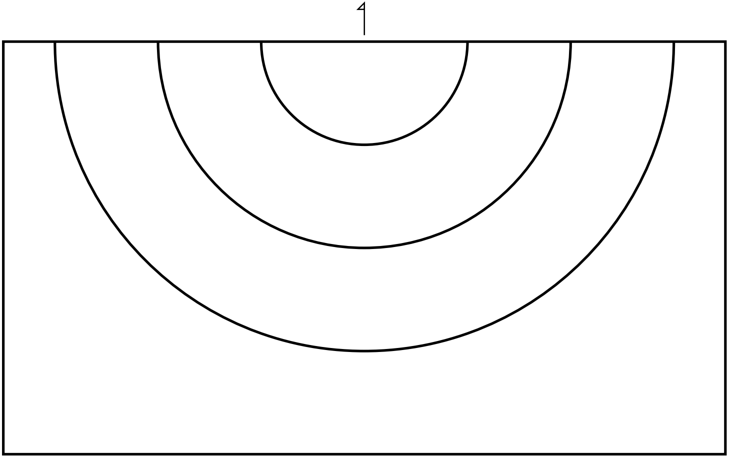
Planewave migration and frequency-dependent velocity smoothing: use and abuse of the ℓ^2 norm.

Chad M. Hogan Gary F. Margrave

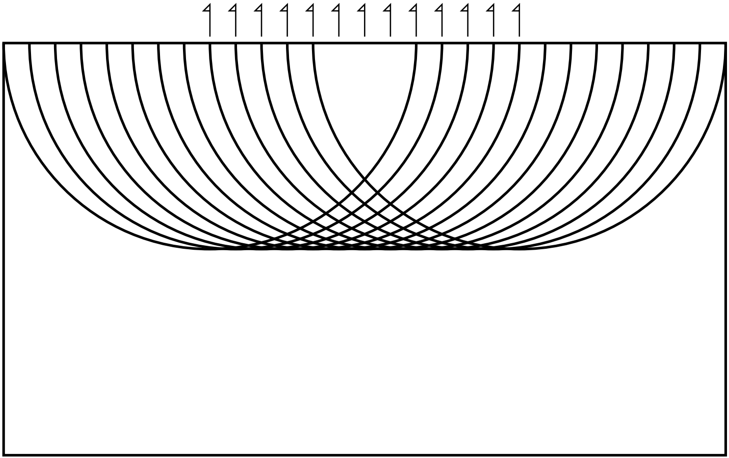
University of Calgary, Department of Geology and Geophysics

CREWES Sponsors Meeting 2006

Plane waves: the idea



Plane waves: the idea



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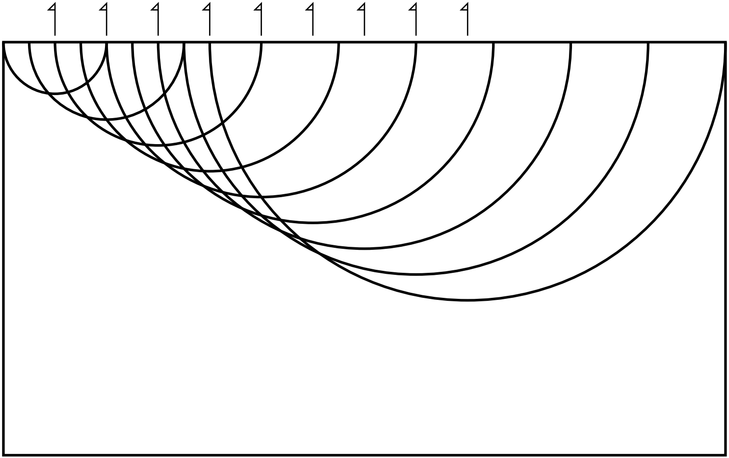
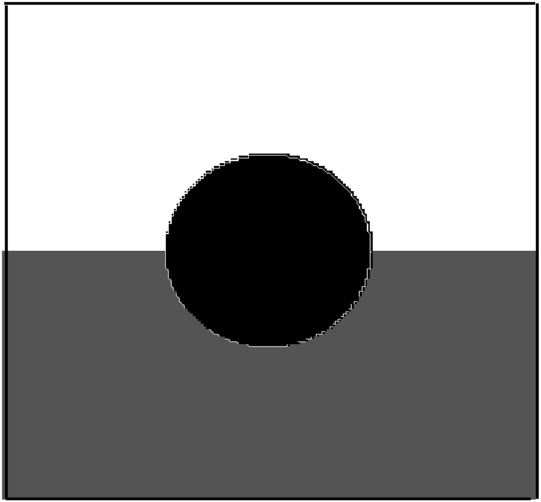
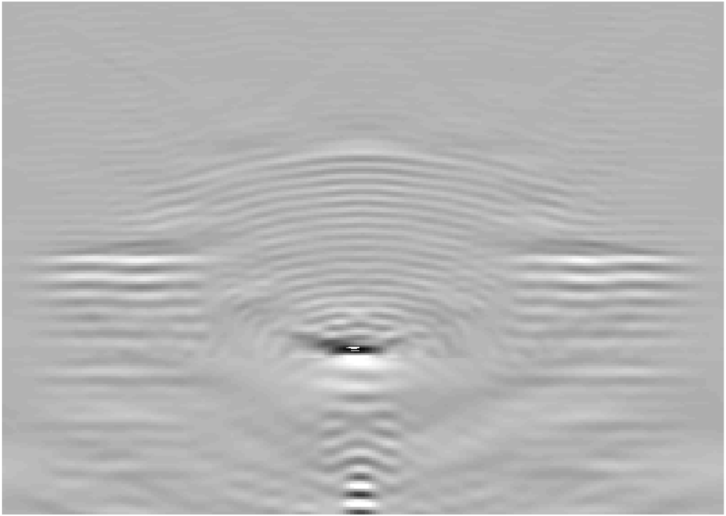


A simple model



Building up a plane-wave image



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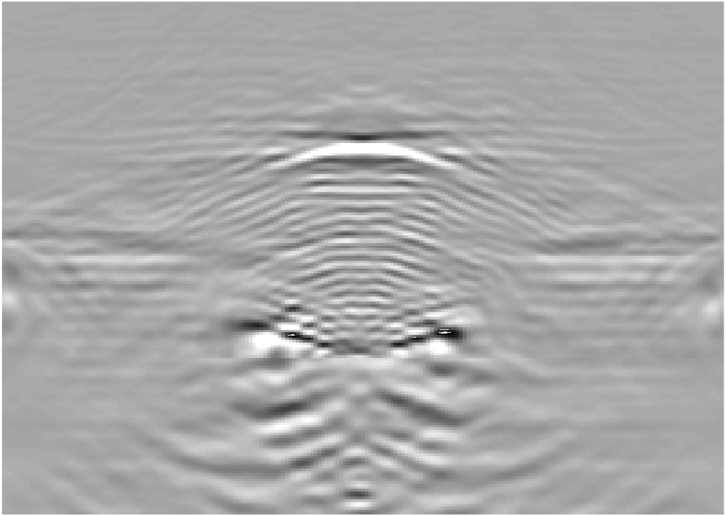

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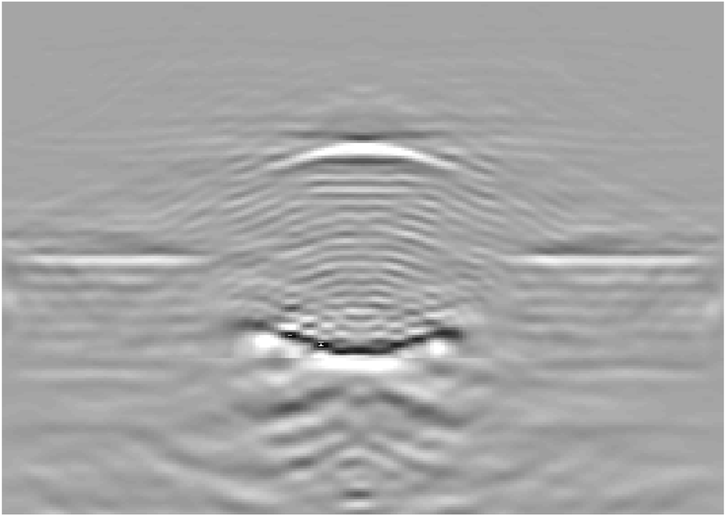

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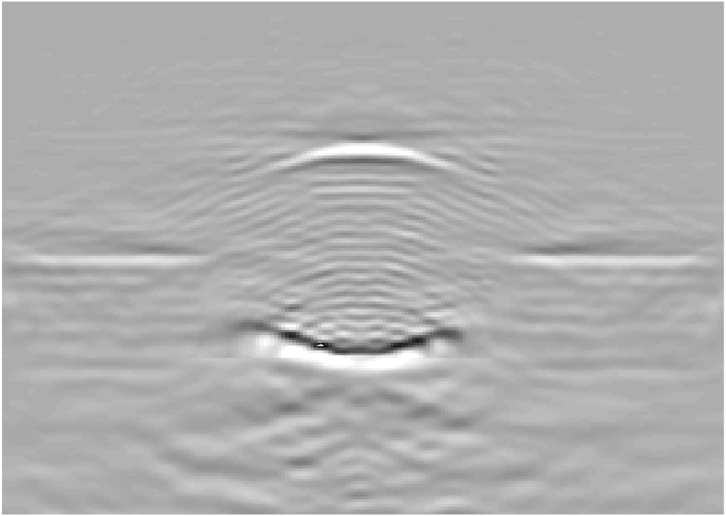

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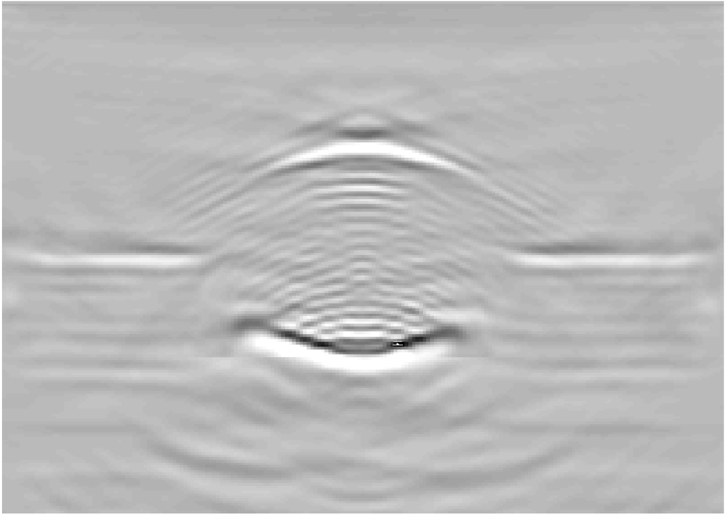
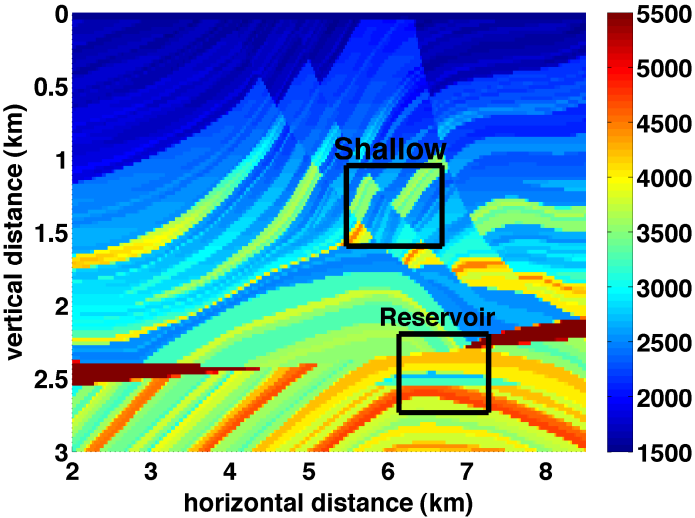
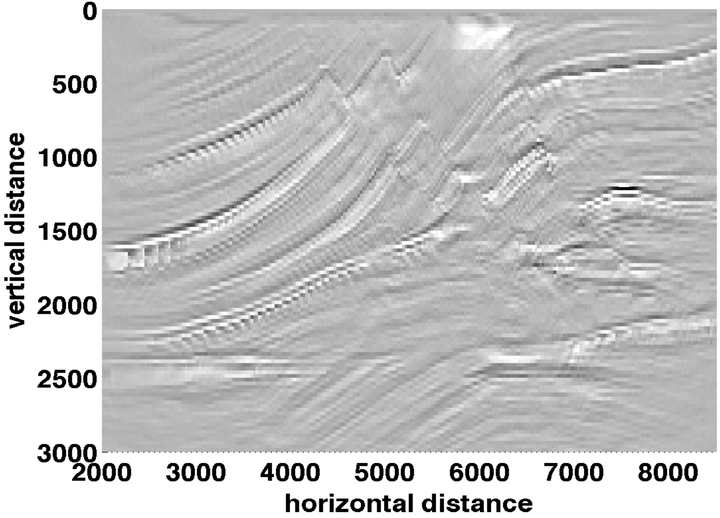


Building up a plane-wave image

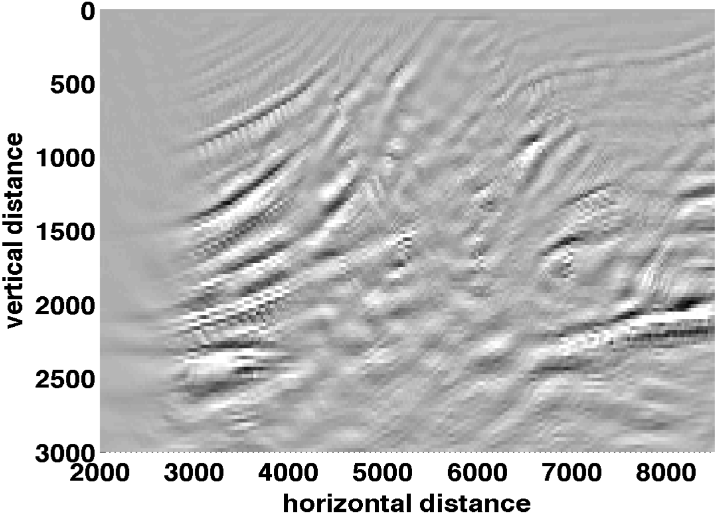
Marmousi imaging



A shot-profile image

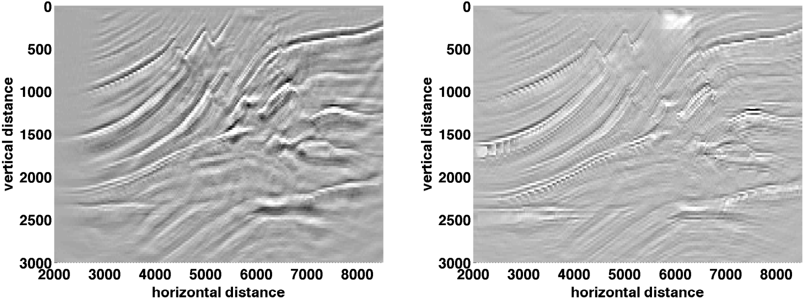


Horizontal plane-wave image



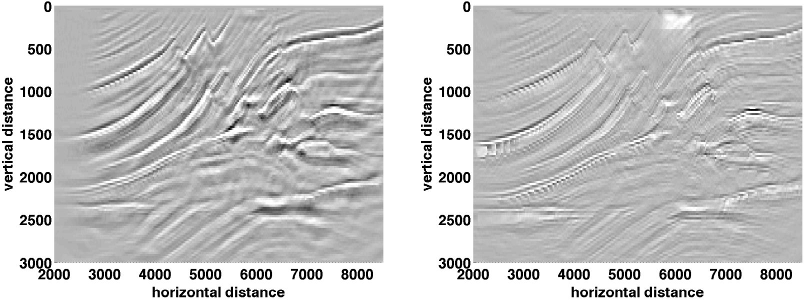
How many plane waves?

41 plane waves:



How many plane waves?

81 plane waves:



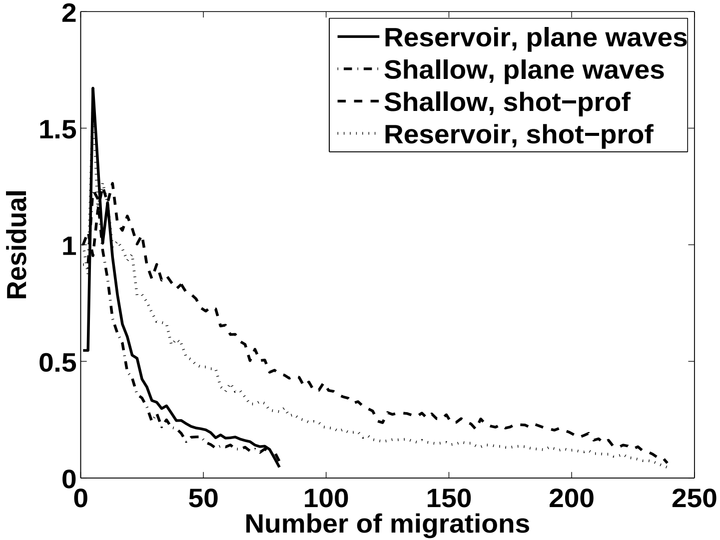
How do we measure convergence?

$$\mathcal{R}(x,z) = \frac{\sqrt{\sum_{x,z} \Omega(x,z)(I_{N+1}(x,z) - I_N(x,z))^2}}{\sqrt{\sum_{x,z} \Omega(x,z)(I_N(x,z))^2}} \tag{1}$$

$\mathcal{R}$ is "residual", Ω is a window isolating a region (e.g. "shallow" or "reservoir"), I_N is one image in a sequence, I_{N+1} is the next.

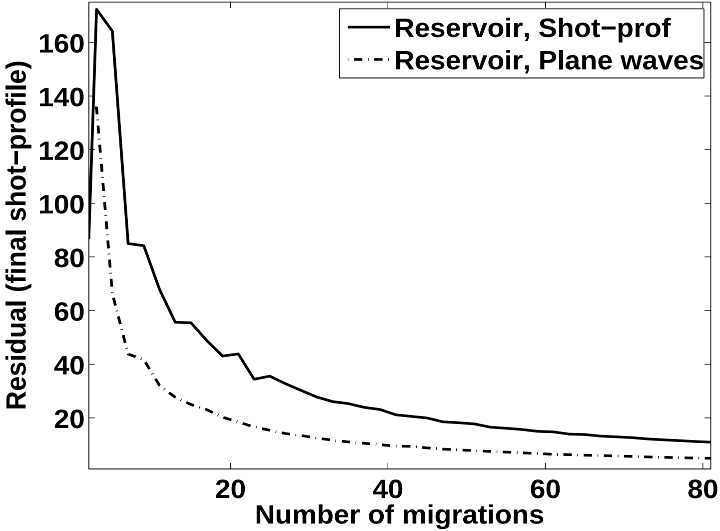
Marmousi image convergence

Convergence within each algorithm:



Marmousi image convergence

Convergence to final shot-profile image:



Generalized PSPI

Infinitesimal extrapolator

$$\Psi(x, z + \Delta z, \omega) = \mathbf{T}_{\alpha(z:z+\Delta z)}\Psi(x, z, \omega)$$

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Infinitesimal extrapolator

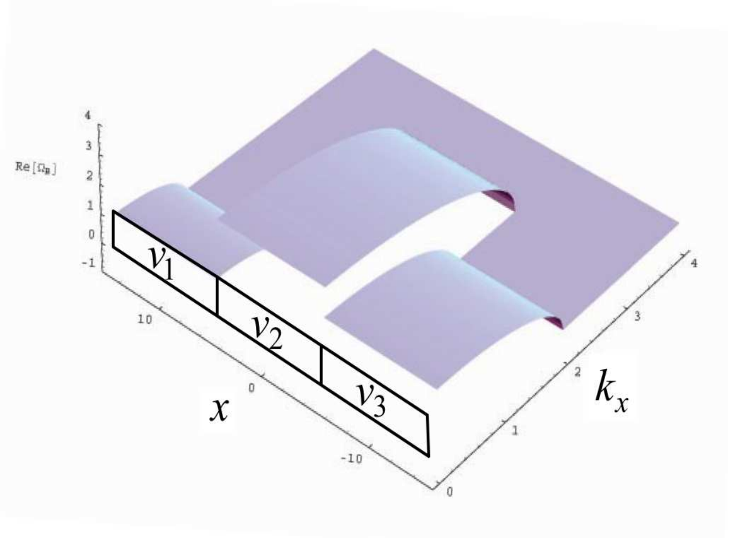
$$\begin{aligned}\Psi(x, z+\Delta z, \omega) &= \mathbf{T}_{\alpha(z:z+\Delta z)}\Psi(x, z, \omega) \\ &\approx \int_{\mathbb{R}} \phi(k_x, z, \omega)\alpha(x, k_x, \omega, z : z+\Delta z)e^{ik_x x}dk_x\end{aligned}$$

where

$$\alpha\left(x, k_x, \omega, z : z+\Delta z\right) = \begin{cases} \exp\left(i\Delta z\sqrt{\frac{\omega^2}{v(x)^2} - k_x^2}\right), & |k_x| \leq \frac{|\omega|}{v(x)} \\ \exp\left(-\left|\Delta z\sqrt{\frac{\omega^2}{v(x)^2} - k_x^2}\right|\right), & |k_x| > \frac{|\omega|}{v(x)} \end{cases}$$

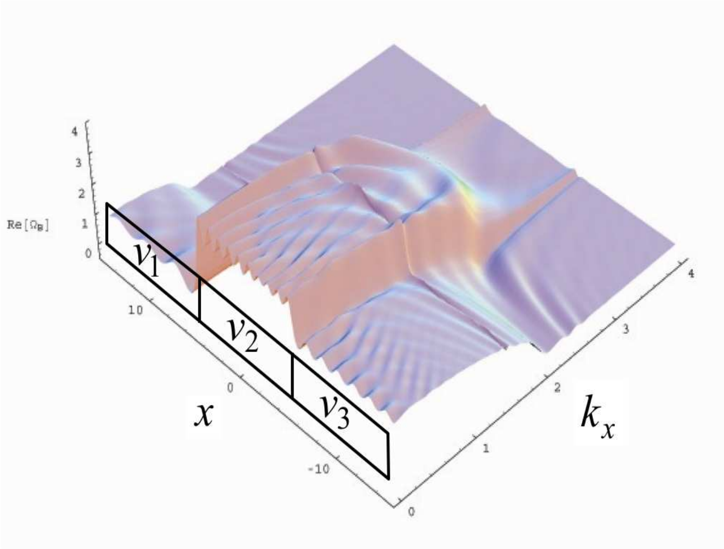
Symbol surfaces

$$Re\left(\sqrt{\frac{\omega^2}{v(x)^2} - k_x^2}\right)$$



Symbol surfaces

$Re\,(\Omega_{\mathbf{B}})$



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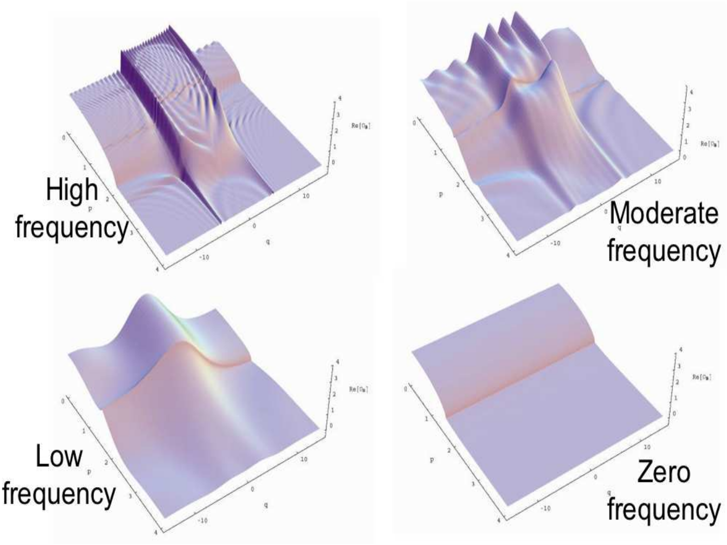

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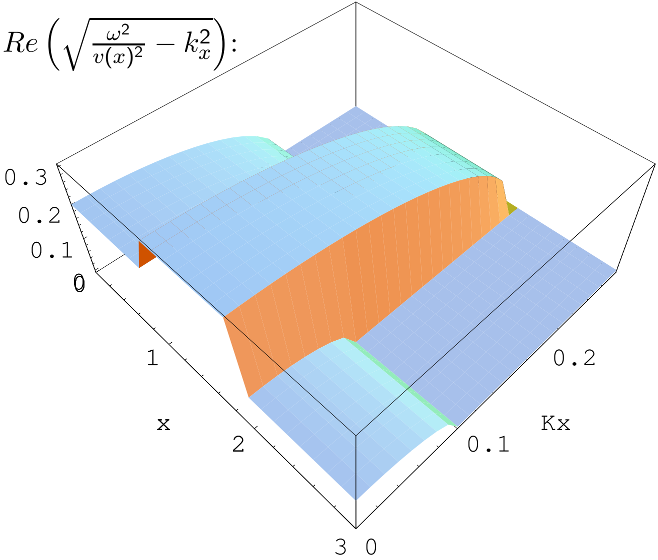
- What would be "correct"? This is still an open question.
- In the meantime, we can just go ahead and do it.
- In fact, we **have** been doing it, via FOCI's spatial resampling.

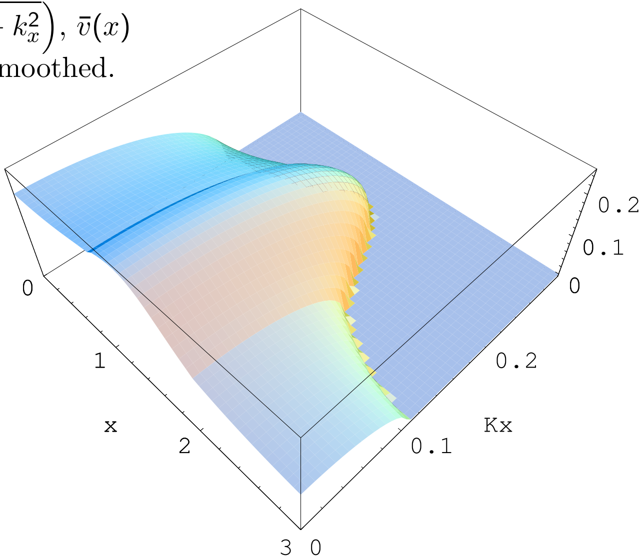
An approximation by smoothing

Original $Re\left(\sqrt{\frac{\omega^2}{v(x)^2} - k_x^2}\right)$:

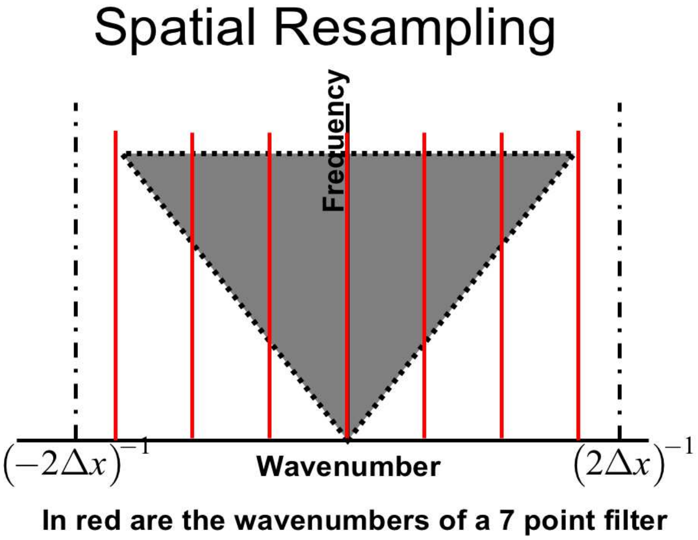


An approximation by smoothing

$Re\left(\sqrt{\frac{\omega^2}{\bar{v}(x)^2} - k_x^2}\right)$, $\bar{v}(x)$
is Gaussian-smoothed.



Spatial resampling in foci



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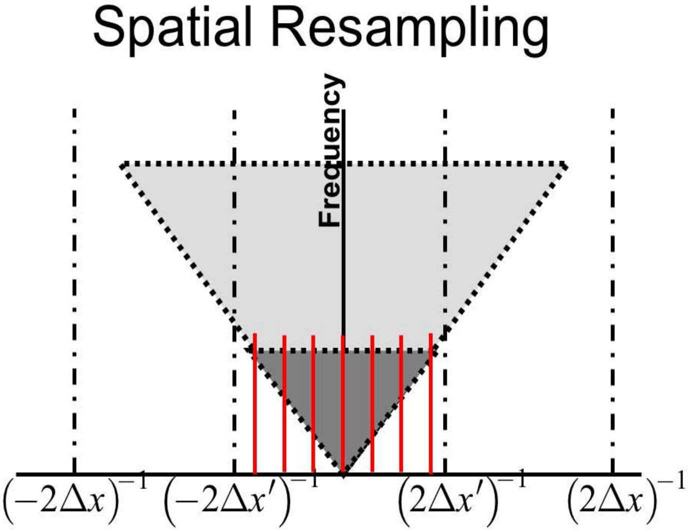

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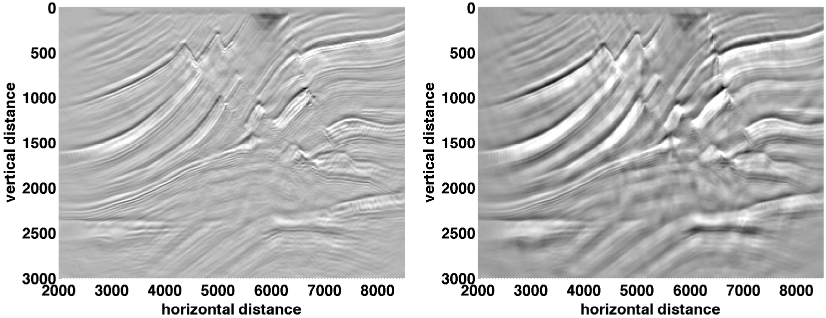
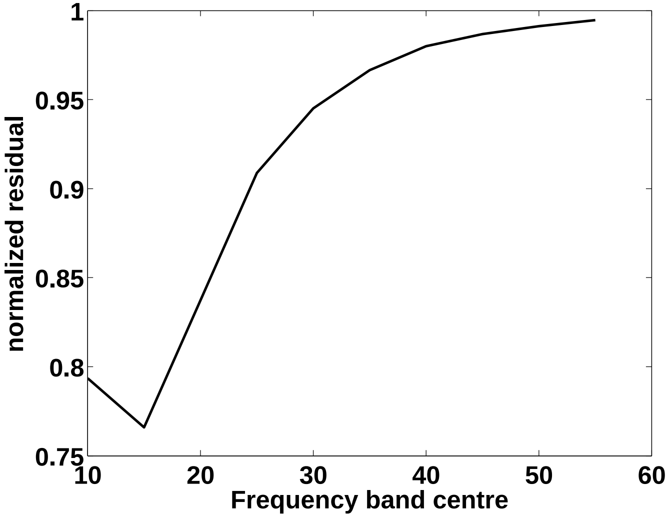


With smoothing on the left, no smoothing on the right

Spatial resampling frequency residuals



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- We should probably do this with raytracing as well.

Acknowledgements

Gary Margrave, Lou Fishman, Michael Lamoureux, and Yongwang Ma.