Reverse-time migration velocity analysis: A real field data example

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Outline

Introduction

- Reverse-time migration can handle strong and sharp contrasts in velocity and anisotropy
- Accurate estimate of seismic velocities is of key importance
- How to automatically obtain velocities using RTM

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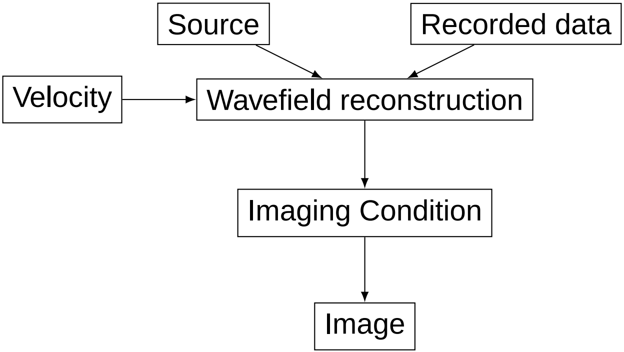
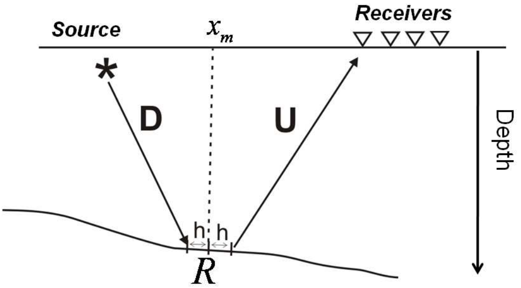
Prestack depth migration



The seismic experiment



D = Downgoing wave

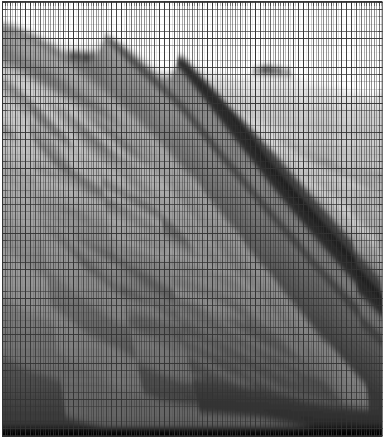
U = Upgoing wave

R = Reflectivity

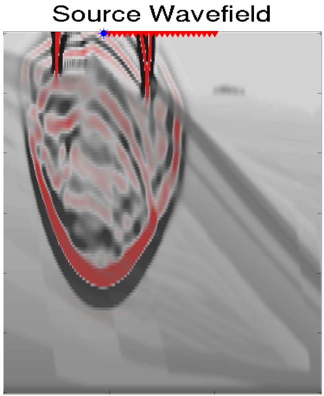
x_m = midpoint

h = half offset

Velocity model representation



Wavefield reconstruction



Anisotropy

Density normalized anisotropic wave equation:

$$\frac{\partial^2 u_i}{\partial t^2}(\mathbf{x}, t) - \frac{\partial}{\partial x_j}\left[v_{ijkl}(\mathbf{x})\frac{\partial u_l}{\partial x_k}(\mathbf{x}, t)\right] = F_i(\mathbf{x}, t)$$

Where v_{ijkl} is the density normalized elasticity tensor.

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Assuming:

- VTI medium

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Assuming:

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- $\delta(\mathbf{x}) = k\varepsilon(\mathbf{x})$

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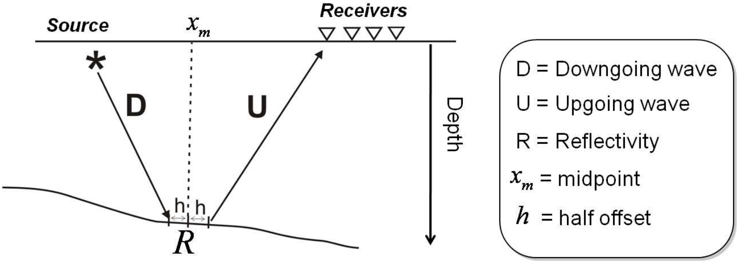
Parameter space reduces to two!

$V_{P0}(\mathbf{x})$ and $\delta(\mathbf{x}) = k\varepsilon(\mathbf{x})$

Imaging condition

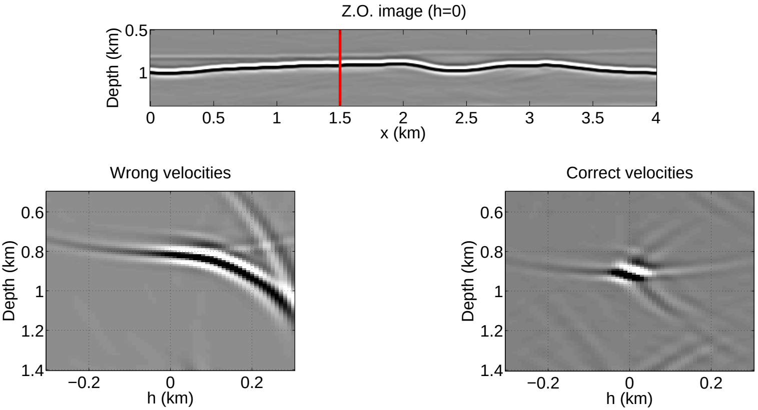
Crosscorrelation imaging condition (Claerbout, 1971)



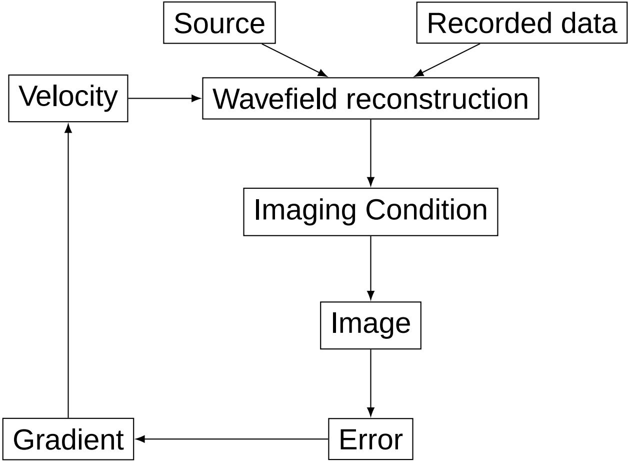
Multi-offset crosscorrelation [Rickett and Sava, 2002]:

$$R(x,h,z) = \sum_s \sum_t U(x+h,z,t,s)D(x-h,z,t,s)$$

Example of CIPs output by RTM



Migration velocity analysis



The error measure

Consider the following error function (Shen, 2003; Weibull and Arntsen 2011):

$$DS = \frac{1}{2}\|h\partial_z R\|^2 = \frac{1}{2}\int dx \int dh \int dz\, h^2(\partial_z R(x,h,z))^2, \quad (1)$$

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The velocity analysis consists of minimizing equation 1 with respect to the parameters $V_{P0}(\mathbf{x})$ and $\delta(\mathbf{x}) = k\varepsilon(\mathbf{x})$.

Summary and remarks

- We present a method to automatically update a velocity model using reverse-time migration
- We show results which prove the feasibility of the method on real data
- The method can potentially be used in complex geological environments
- High computational cost is limiting its use to 2D and low frequency datasets

Acknowledgements

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Chavent, G., 2009, Nonlinear least squares for inverse problems. Theoretical foundations and step by step guide for applications: Springer.

Rickett, J. E., and P. C. Sava, 2002, Offset and angle-domain common image-point gathers for shot-profile migration: Geophysics, **67**, 883–889.

Shen, P., and W. W. Symes, 2008, Automatic velocity analysis via shot profile migration: Geophysics, **73**, 49–59.

Symes, W. W., and J. J. Carazzone, 1991, Velocity inversion by differential semblance optimization: Geophysics, **5**, 654–663.