ROSE Meeting

Surface related multiple elimination through inversion

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Trondheim
May 6th 2014

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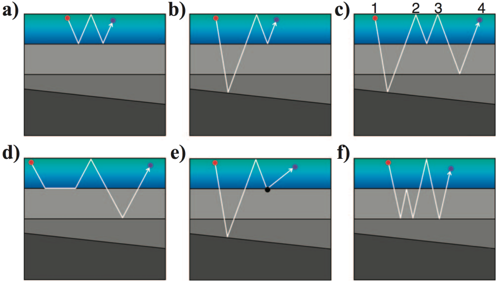
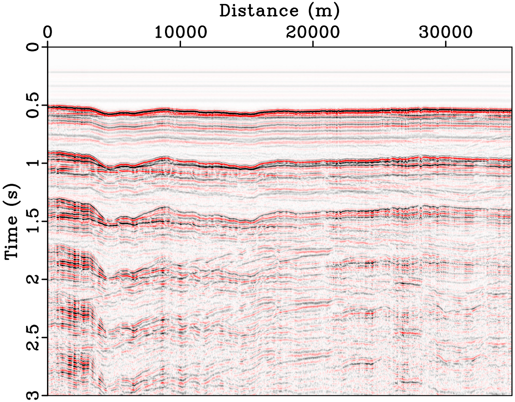
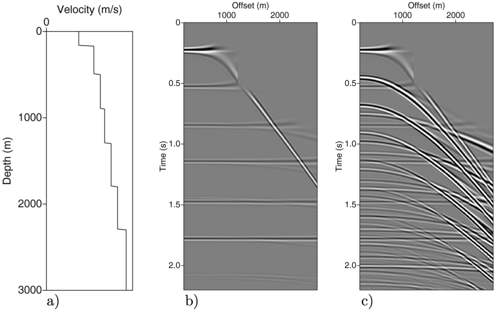
Surface related multiples



(Dragoset et al., 2010)



Surface related multiples



(Verschuur et al., 2006)

- Most velocity analysis methods are based on single-scattering assumptions
- Multiples and primaries occur at same zero offset traveltimes but have conflicting moveouts
- Imaging of multiple reflections require first separation of primaries and multiples

Outline

Surface related multiple elimination (SRME)

Estimation of primaries by sparse inversion (EPSI)

Multiple attenuation by up and down deconvolution (MAUDD)

Summary

Some seismic demultiple methods

- Surface related multiple elimination (Verschuur et al., 1992)
- Inverse scattering series methods (Weglein, 1997)
- Up/Down deconvolution using dual component measurements (Amundsen, 2001)
- Estimation of primaries by sparse inversion (van Groenestijn and Verschuur, 2009)

SRME

1D SRME

F-K theory

Forward model for the reflection response (recorded data - direct arrival)

$$P_r(\omega, \mathbf{k}) = \mathcal{S}(\omega, \mathbf{k}) \frac{\mathcal{R}(\omega, \mathbf{k})}{1 + r_0 \mathcal{R}(\omega, \mathbf{k})}$$

where r_0 is the reflection coefficient at the free surface (typically equal to 1)

1D SRME

F-K theory

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where r_0 is the reflection coefficient at the free surface (typically equal to 1)

If $r_0 = 0$ we get

$$P_r(\omega, \mathbf{k}) = P_p(\omega, \mathbf{k}) = \mathcal{S}(\omega, \mathbf{k})\mathcal{R}(\omega, \mathbf{k})$$

1D SRME

F-K theory

Reorganizing the forward model for reflection data we get

$$P_p = \mathcal{S}\mathcal{R} = \frac{P_r}{1 - \mathcal{S}^{-1} r_0 P_r}$$

Expanding the fraction in a Taylor series

$$P_p = P_r[1 + r_0\mathcal{S}^{-1}P_r + (r_0\mathcal{S}^{-1}P_r)^2 + (r_0\mathcal{S}^{-1}P_r)^3 + ...]$$

From which we can recognize the iterative form of SRME

$$P_p^{(i+1)} = P_r + \mathcal{A}P_p^{(i)}P_r$$

where $\boxed{\mathcal{A} = r_0\mathcal{S}^{-1}}$

1D SRME

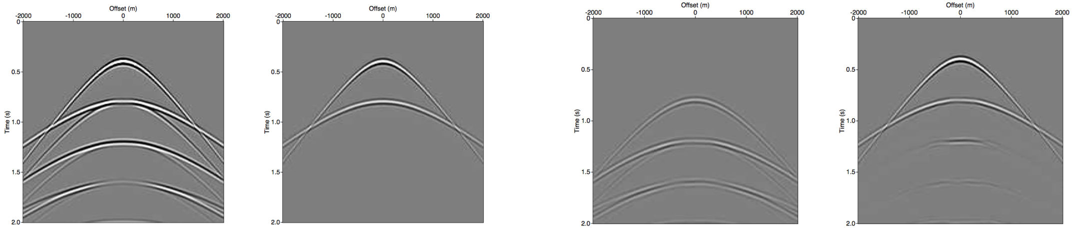
F-K theory

Minimum energy assumption

To determine $\mathcal{A}$, Verschuur et al. (1992) propose to minimize the following functional

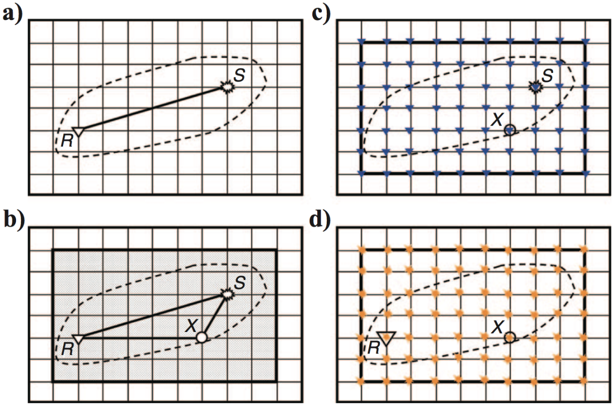
$$E = \|P_p^{(i+1)} - P_r - \mathcal{A}P_p^{(i)}P_r\|_2$$

This is based on the ad-hoc assumption that the primaries have minimum energy

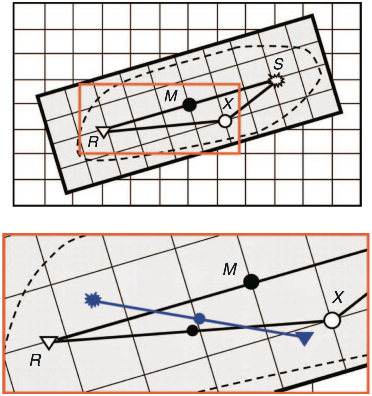


a) b) c) d)

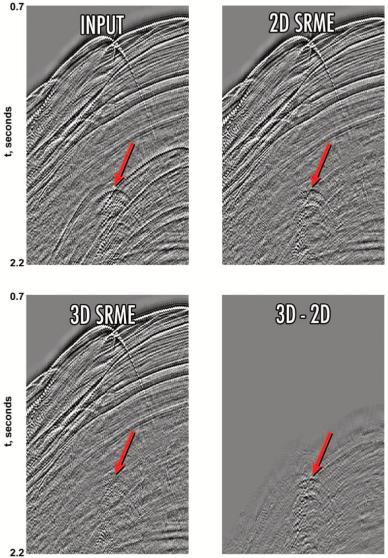
3D SRME



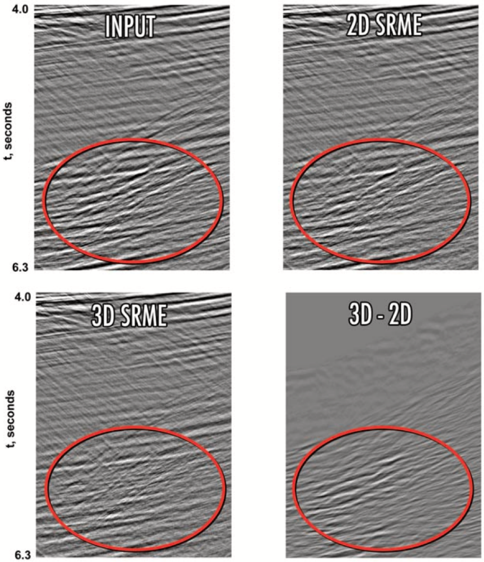
(Dragoset et al., 2010)



$$P_p^{(i+1)}(\mathbf{x}_r,\omega;\mathbf{x}_s) = P_r(\mathbf{x}_r,\omega;\mathbf{x_s}) + \mathcal{A}(\omega)\int d\chi P_p^{(i)}(\mathbf{x}_r,\omega;\chi)P_r(\chi,\omega;\mathbf{x}_s)$$



(Baumstein et al., 2005)



EPSI

Estimation of primaries by sparse inversion (EPSI)

FK theory

$$P_r(\omega, \mathbf{k}) = \mathcal{S}(\omega, \mathbf{k}) \frac{\mathcal{R}(\omega, \mathbf{k})}{1 + r_0 \mathcal{R}(\omega, \mathbf{k})}$$

$$P_r(\omega, \mathbf{k}) = \mathcal{S}(\omega, \mathbf{k}) \mathcal{R}(\omega, \mathbf{k}) - r_0 \mathcal{R}(\omega, \mathbf{k}) P_r(\omega, \mathbf{k})$$

EPSI error function

$$J = \| P_r(\omega, \mathbf{k}) - \mathcal{S}(\omega) \mathcal{R}(\omega, \mathbf{k}) + r_0 \mathcal{R}(\omega, \mathbf{k}) P_r(\omega, \mathbf{k}) \|_2$$

Estimation of primaries by sparse inversion (EPSI)

FK theory

EPSI error function

$$J = \|P_r(\omega,\mathbf{k}) - \mathcal{S}(\omega)\mathcal{R}(\omega,\mathbf{k}) + r_0\mathcal{R}(\omega,\mathbf{k})P_r(\omega,\mathbf{k})\|_2$$

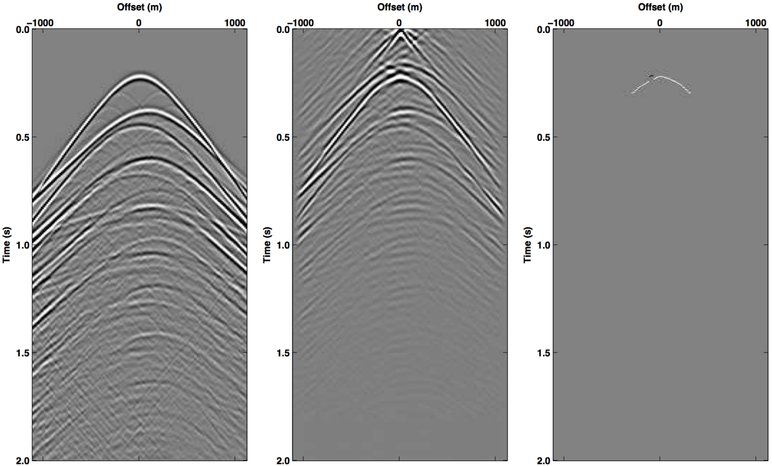
The objective function is minimized using gradient based methods

$$\frac{\partial J}{\partial \mathcal{R}} = (\mathcal{S} - r_0 P_r)^H (P_r - \mathcal{S}\mathcal{R} + r_0\mathcal{R}P_r)$$

$$\frac{\partial J}{\partial \mathcal{S}} = \mathcal{R}^H (P_r - \mathcal{S}\mathcal{R} + r_0\mathcal{R}P_r)$$

The solution of this problem requires sparsity constraints on $\boxed{\mathcal{R}}$, and time windowing on $\boxed{\mathcal{S}}$ (van Groenestijn and Verschuur, 2009; Lin & Herrmann, 2010).

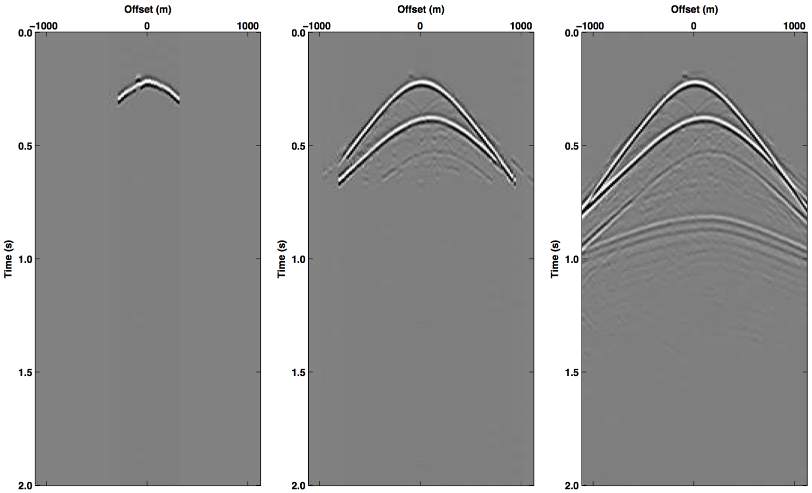
Estimation of primaries by sparse inversion (EPSI)



a) b) c)

(van Groenestijn and Verschuur, 2009)

Estimation of primaries by sparse inversion (EPSI)



a) iteration i=1 b) iteration i=10 c) iteration i=30

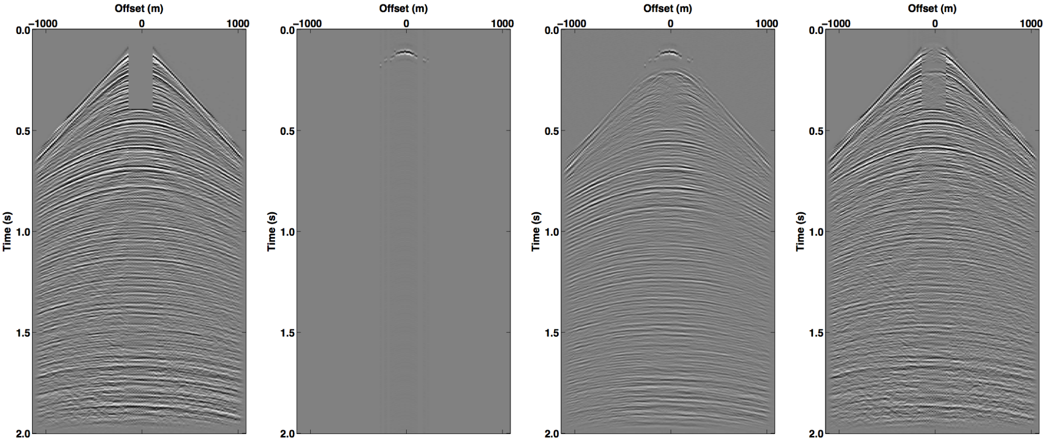
(van Groenestijn and Verschuur, 2009)

Estimation of primaries by sparse inversion (EPSI)

Advantages over SRME

- Near offset reconstruction
- Avoids the adaptive subtraction step
- Works equally well with short period and long period multiples

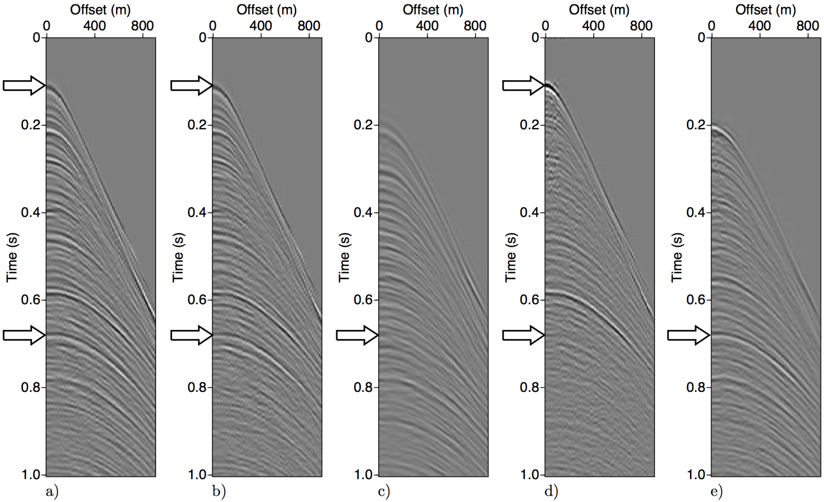
Estimation of primaries by sparse inversion (EPSI)



a) b) c) d)

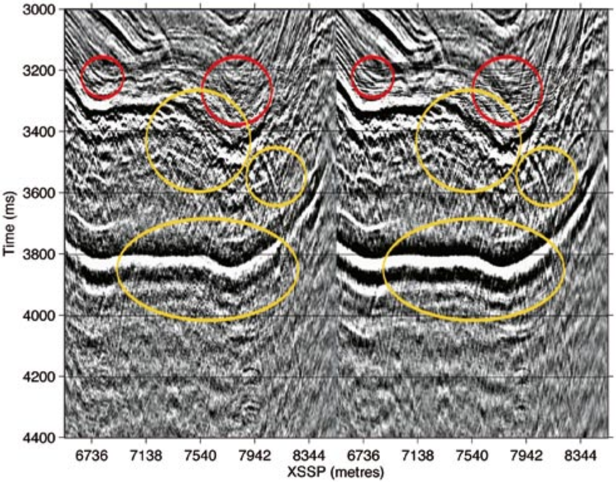
(van Groenestijn and Verschuur, 2009)

Estimation of primaries by sparse inversion (EPSI)



(van Groenestijn and Verschuur, 2009)

Estimation of primaries by sparse inversion (EPSI)



(Savels et al., 2011)

MAUDD

Multiple attenuation by up and down deconvolution (MAUDD)

Up and down deconvolution using pressure and vertical particle velocity measurements in 1D media

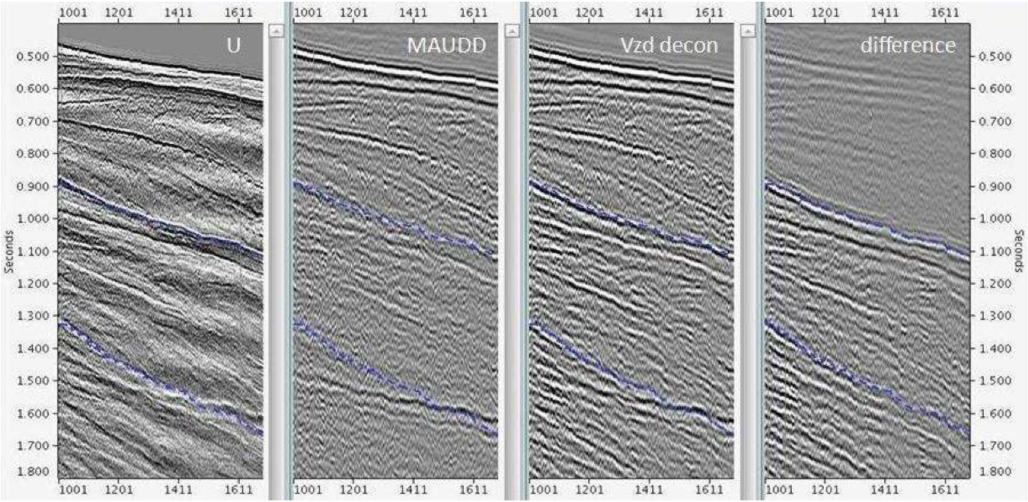
$$P_p(\omega, \mathbf{k}) = -\mathcal{S}_d(\omega, \mathbf{k}) \frac{P}{2i\omega\rho\mathcal{D}_{v_z}}(\omega, \mathbf{k})$$

where $\mathcal{D}_{v_z}$ is the down going component of the vertical particle velocity, and ρ is the density of the water.

Extension to 3D inhomogeneous media by Amundsen (2001)

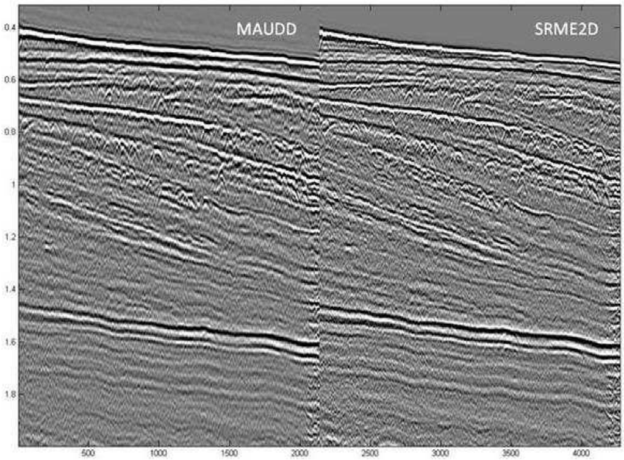
$$P(\mathbf{x}_r, \omega; \mathbf{x}_s) = -2i\omega\rho\mathcal{S}_d(\omega) \int d\chi P_p(\mathbf{x}_r, \omega; \chi)\mathcal{D}_{v_z}(\chi, \omega; \mathbf{x}_s)$$

Multiple attenuation by up and down deconvolution (MAUDD)



(Majdanski et al., 2010)

Multiple attenuation by up and down deconvolution (MAUDD)



(Majdanski et al., 2010)

Summary

- I reviewed three wave theoretic methods that can be used to attenuate surface related multiples on seismic data
- The methods are fully data driven, and require no knowledge of the subsurface structure
- The data acquisition requirements for full 3D implementation are hard to meet in practice, which call for efficient interpolation/extrapolation workarounds
- None of the methods gives perfect results, which means that methods based on signal processing such as FK and Radon demultiple methods can still be useful to remove the remaining multiple energy

Acknowledgments

The author acknowledge the sponsors of the Rose consortium for financial support.

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