Image-guided WEMVA for azimuthal anisotropy

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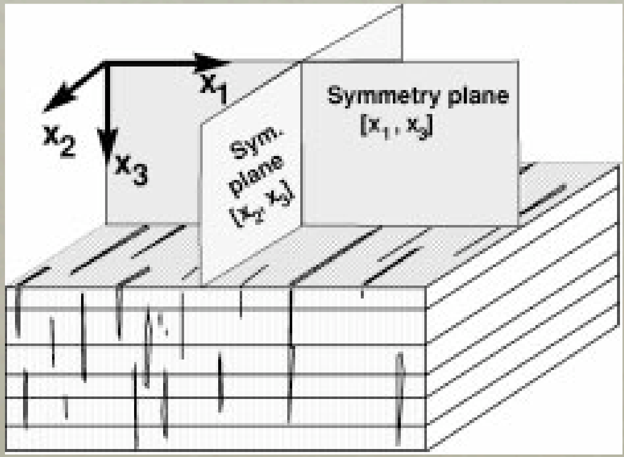
SEP-149, pp307 – 318

Agenda

- Motivation
- Theory
- Example
- Conclusions

Motivation

- **Orthorhombic medium**
  - ➢ **Parallel vertical cracks + VTI**
  - ➢ **Two sets of cracks at a certain angle**

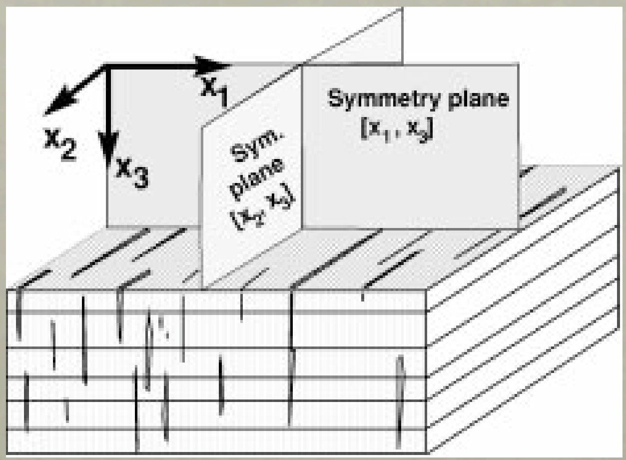


Tsvankin, 1997

Motivation

- **Orthorhombic medium**

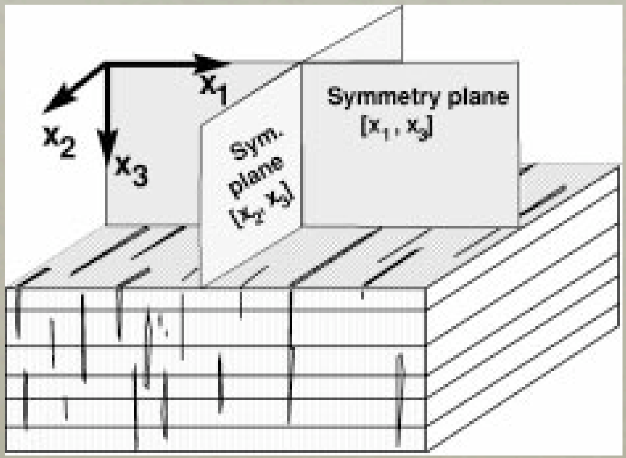
$$\begin{pmatrix} c_{11} & c_{12} & c_{13} & 0 & 0 & 0 \\ c_{12} & c_{22} & c_{23} & 0 & 0 & 0 \\ c_{13} & c_{23} & c_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & c_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & c_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & c_{66} \end{pmatrix}$$



Tsvankin, 1997

Motivation

- **Orthorhombic medium**
  - ➢ **Kinematics of wave propagation in the symmetric planes: [x1, x3], [x2, x3] and [x1, x2] are fully described by VTI equations.**



Tsvankin, 1997

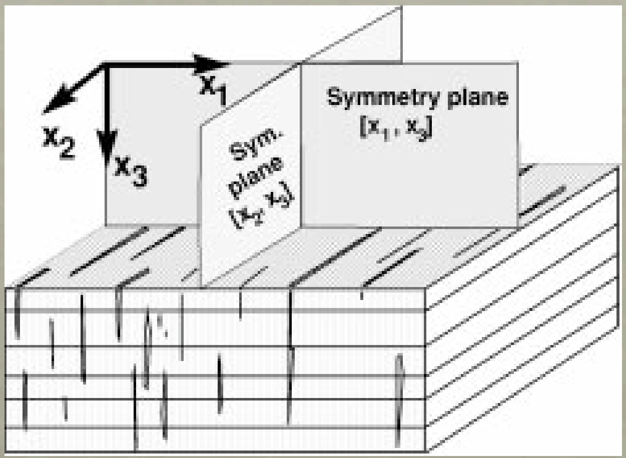
Motivation

- **Orthorhombic medium**

$$V_p(\theta, \phi) = V_{p0}[1 + \delta(\phi)\sin^2\theta\cos^2\theta + \epsilon(\phi)\sin^4\theta]$$

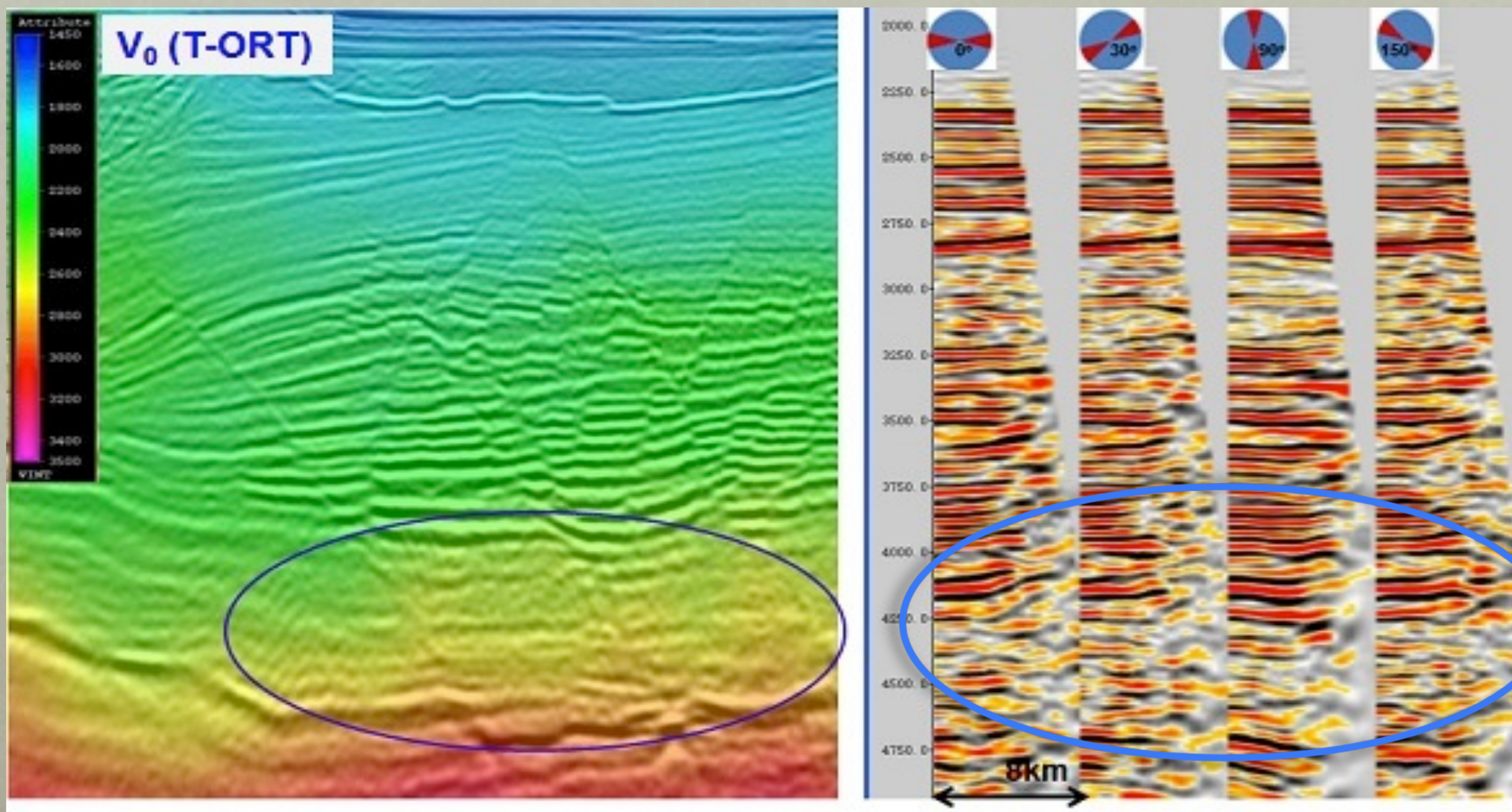
where

$$\epsilon(\phi) = \epsilon^{(1)}\sin^4\phi + \epsilon^{(2)}\cos^4\phi + (2\epsilon^{(2)} + \delta^{(3)})\sin^2\phi\cos^2\phi$$
$$\delta(\phi) = \delta^{(1)}\sin^2\phi + \delta^{(2)}\cos^2\phi$$



Tsvankin, 1997

Motivation



Zhang et al. (2012)

Objective function

- **WEMVA objective function** (Biondi, 2006)

$$J = ||\mathbf{W}(\mathbf{h})\mathbf{I}(\mathbf{x},\mathbf{h})||_2^2$$

$\mathbf{I}(\mathbf{x},\mathbf{h})$: Common image gathers in subsurface offset $\mathbf{h}$

$\mathbf{W}(\mathbf{h})$: weighting function

Objective function

- **DSO objective function** (Shen and Symes, 2004)

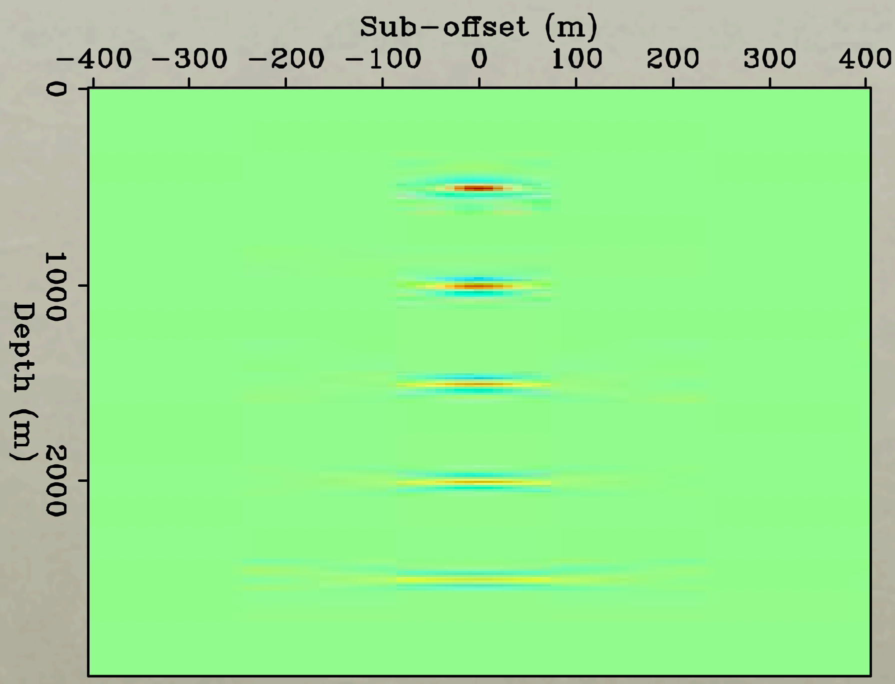
$$J = ||\mathbf{W}(\mathbf{h})\mathbf{I}(\mathbf{x}, \mathbf{h})||_2^2$$

$$\mathbf{W}_{\mathrm{dso}}(\mathbf{x}, \mathbf{h}) = \frac{h}{h_{max}}$$

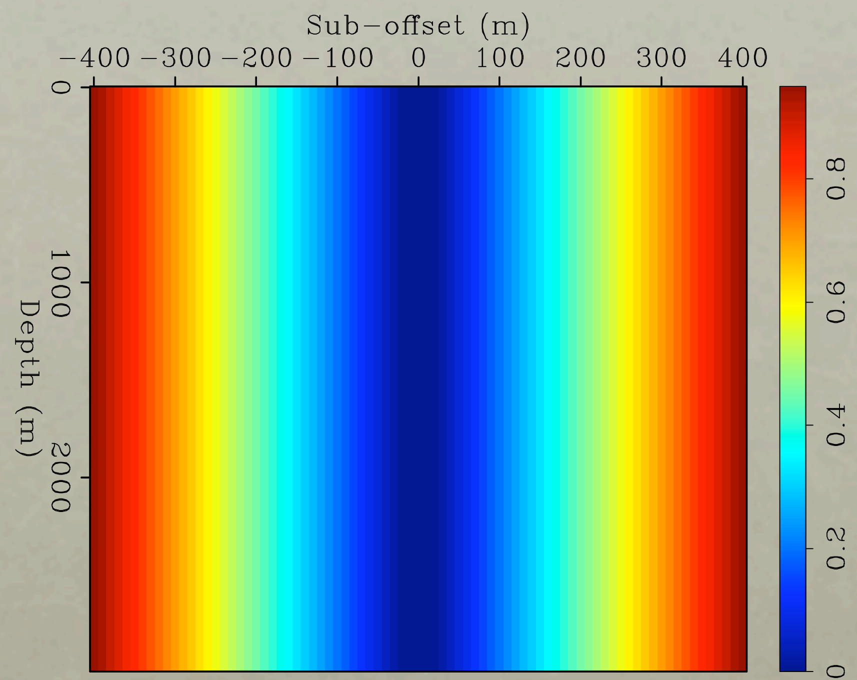
$h :$ Length of the subsurface offset $\mathbf{h}$

$\mathbf{I}(\mathbf{x}, \mathbf{h}) :$ Subsurface common image gathers

Objective function



Subsurface offset CIG



DSO weighting function

Objective function

- **Image-guided objective function (Shragge and Lumley, 2013)**

$$J = ||\mathbf{W}(\mathbf{h})\mathbf{I}(\mathbf{x},\mathbf{h})||_2^2$$

$$\mathbf{W}_{\text{img}}(\mathbf{x},\mathbf{h}) = 1 - \frac{E(\mathbf{I_0}(\mathbf{x},\mathbf{h}))}{\max(E(\mathbf{I_0}(\mathbf{x},\mathbf{h})))}$$

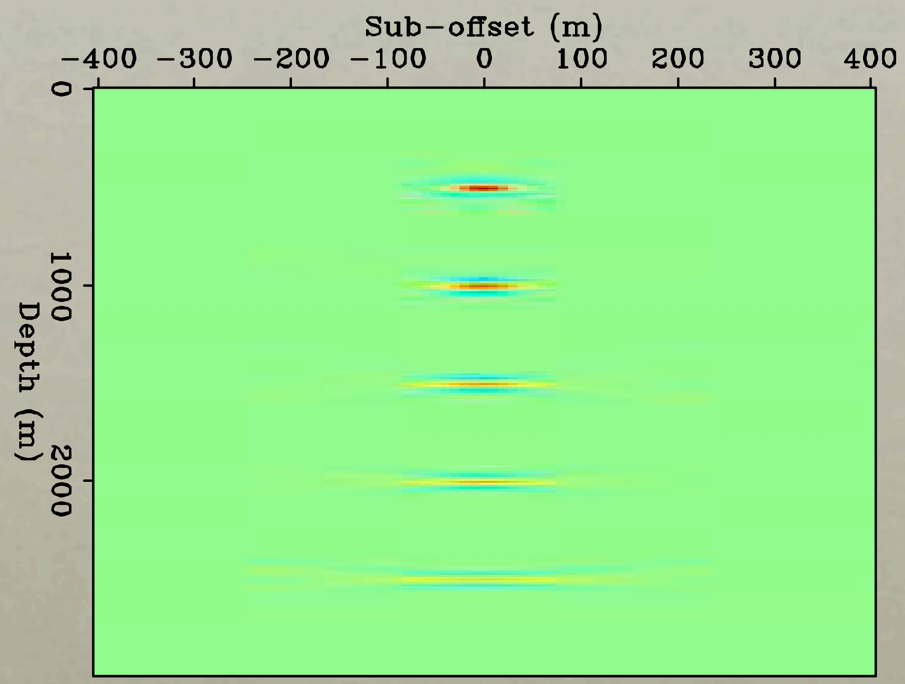
$\mathbf{I}(\mathbf{x},\mathbf{h})$: Subsurface common image gathers at a certain azimuth

$\mathbf{I_0}(\mathbf{x},\mathbf{h})$: Subsurface common image gathers at the reference azimuth

$E\{.\}$: denotes the application of the envelope function

max : takes the maximum value in the $(\mathbf{x},\mathbf{h})$ domain

Objective function



Subsurface offset CIG

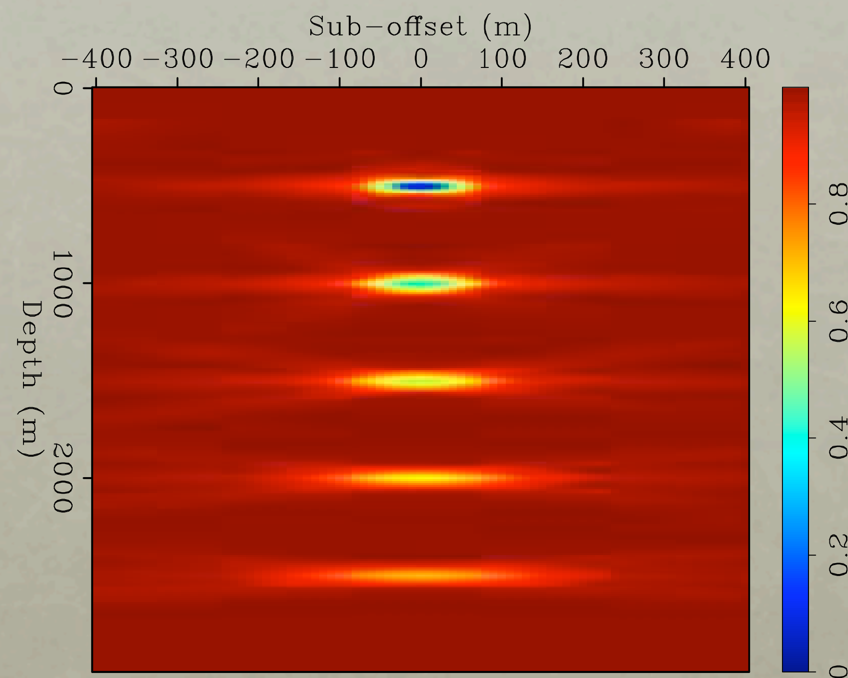
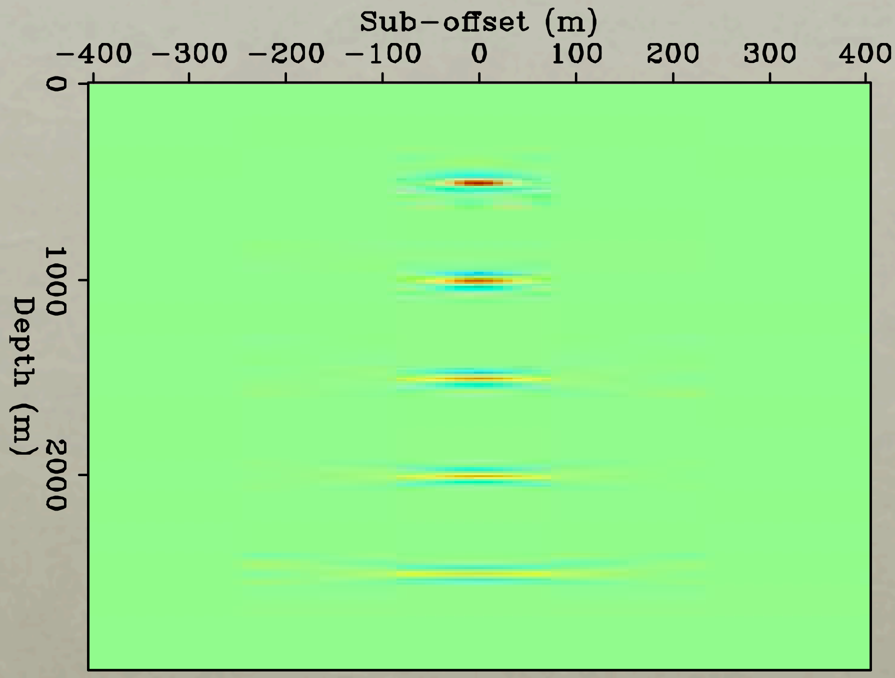


Image-guided weighting function

Accurate vertical velocity

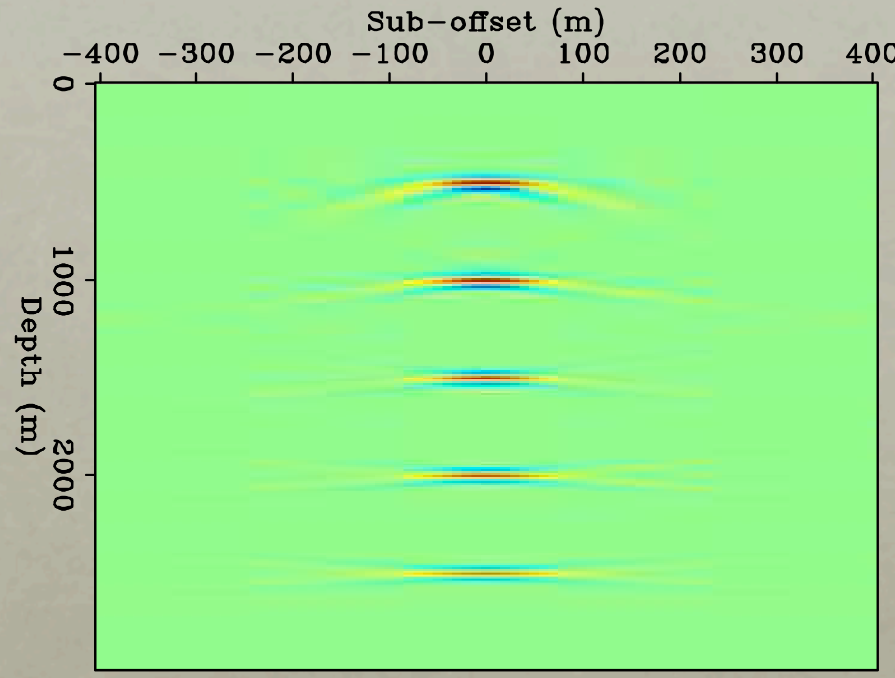
Image at azimuth 0°



$V_{p0_t} = 2000m/s, \eta_t = 0.2, \delta_t = 0.1$

$V_{p0_m} = 2000m/s, \eta_m = 0.2, \delta_m = 0.1$

Image at azimuth 90°



$V_{p0_t} = 2000m/s, \eta_t = 0.4, \delta_t = 0.1$

$V_{p0_m} = 2000m/s, \eta_m = 0.2, \delta_m = 0.1$

Accurate vertical velocity

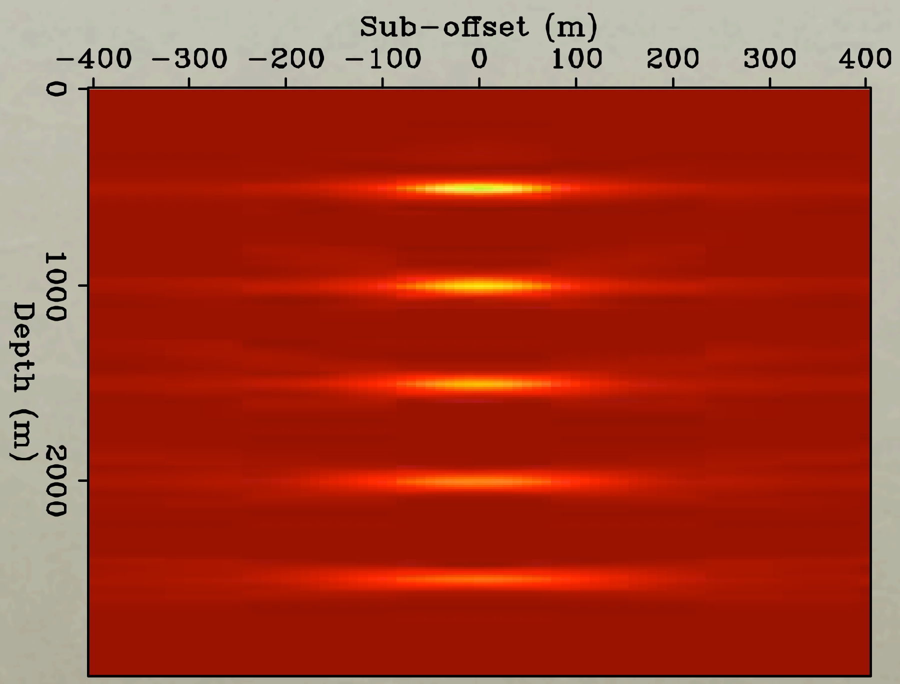
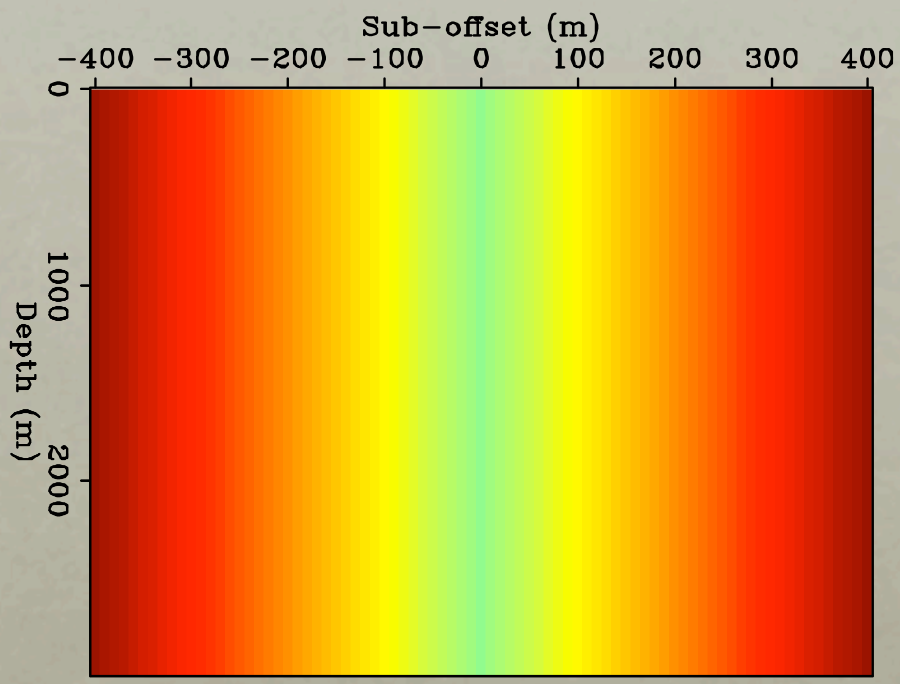


Image-guided weighting function



DSO weighting function

Accurate vertical velocity

Residual image at azimuth 90°

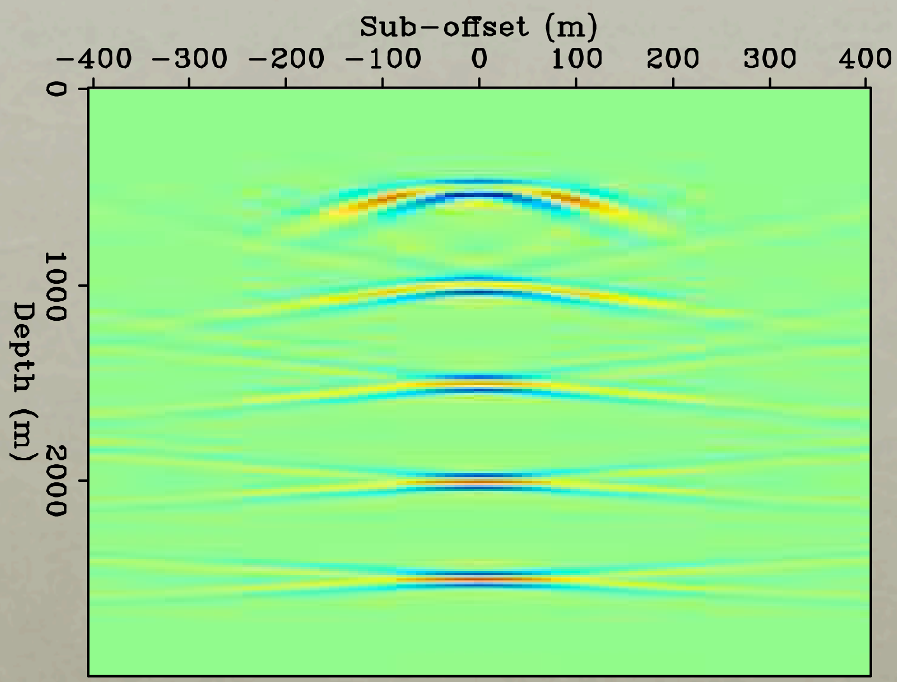
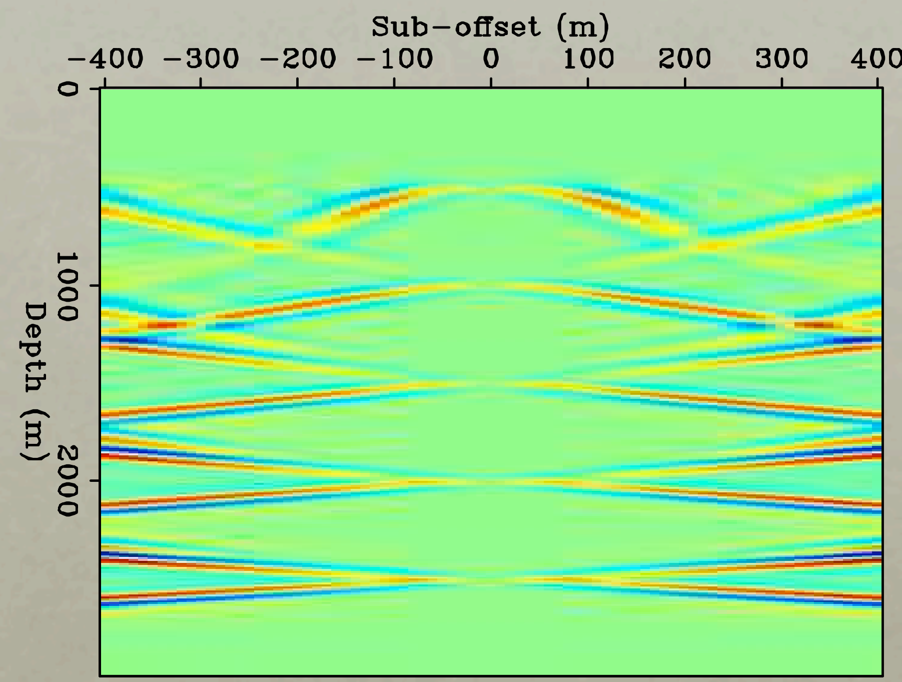


Image-guided weighting function

Residual image at azimuth 90°



DSO weighting function

Accurate vertical velocity

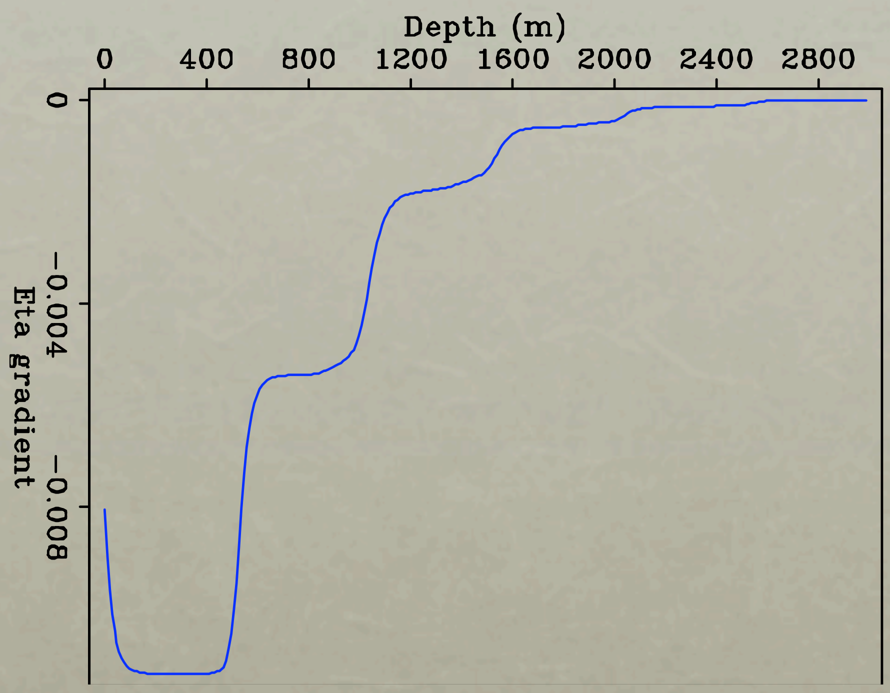
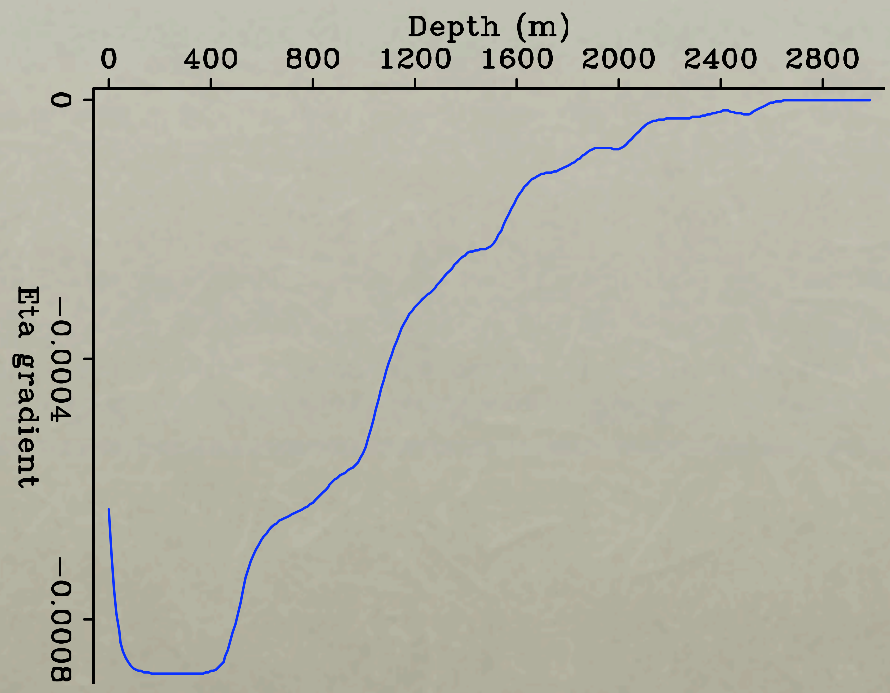


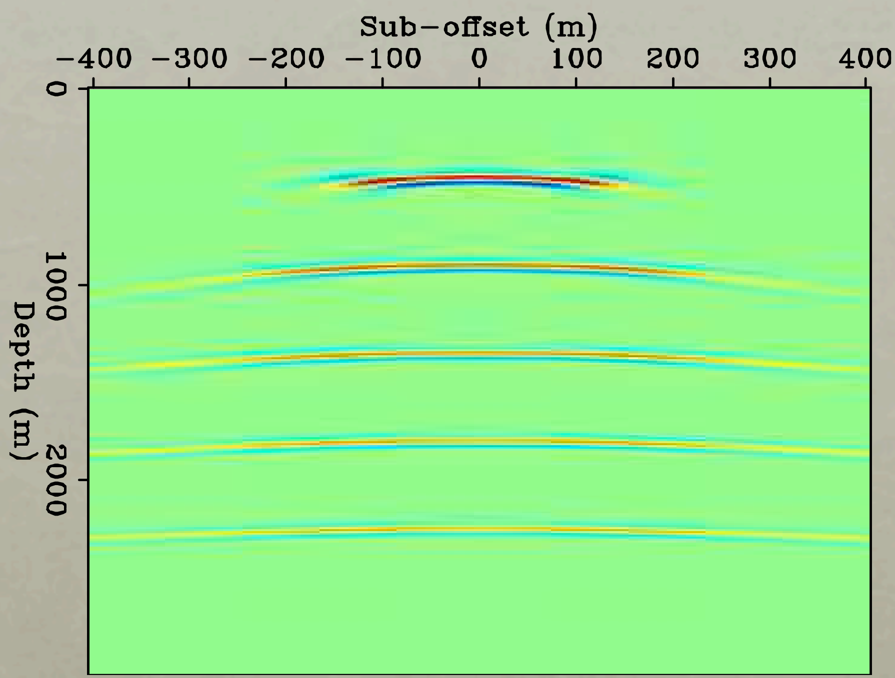
Image-guided weighting function



DSO weighting function

Under-migration

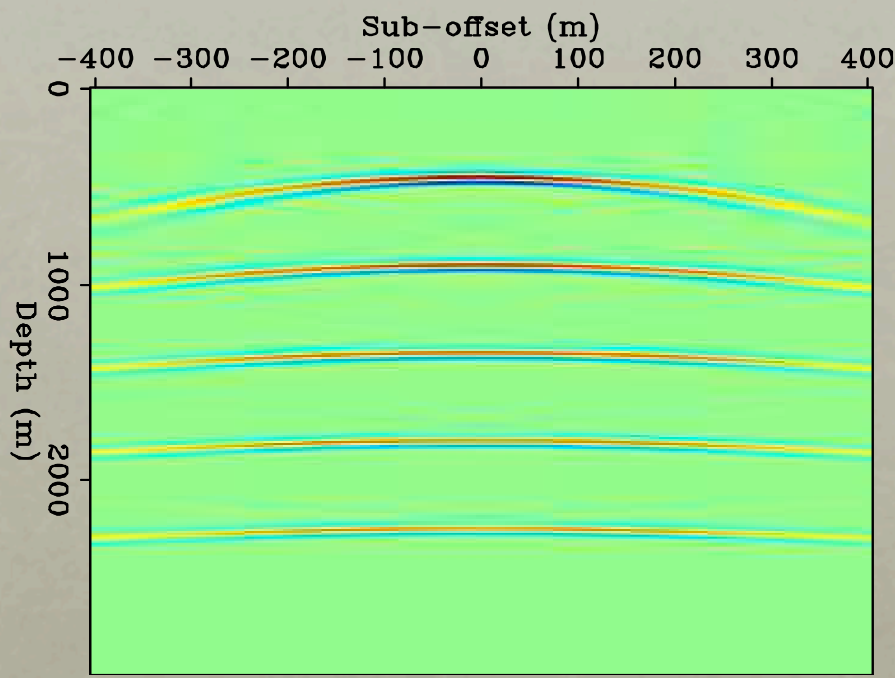
Image at azimuth 0°



$V_{p0_t} = 2000m/s, \eta_t = 0.2, \delta_t = 0.1$

$V_{p0_m} = 1800m/s, \eta_m = 0.2, \delta_m = 0.1$

Image at azimuth 90°



$V_{p0_t} = 2000m/s, \eta_t = 0.4, \delta_t = 0.1$

$V_{p0_m} = 1800m/s, \eta_m = 0.2, \delta_m = 0.1$

Under-migration

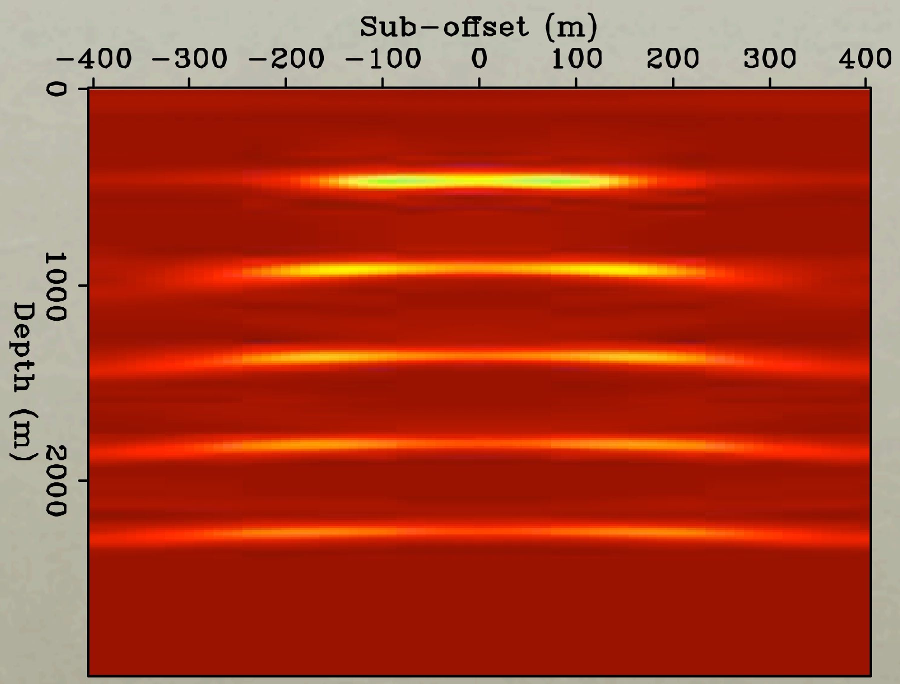
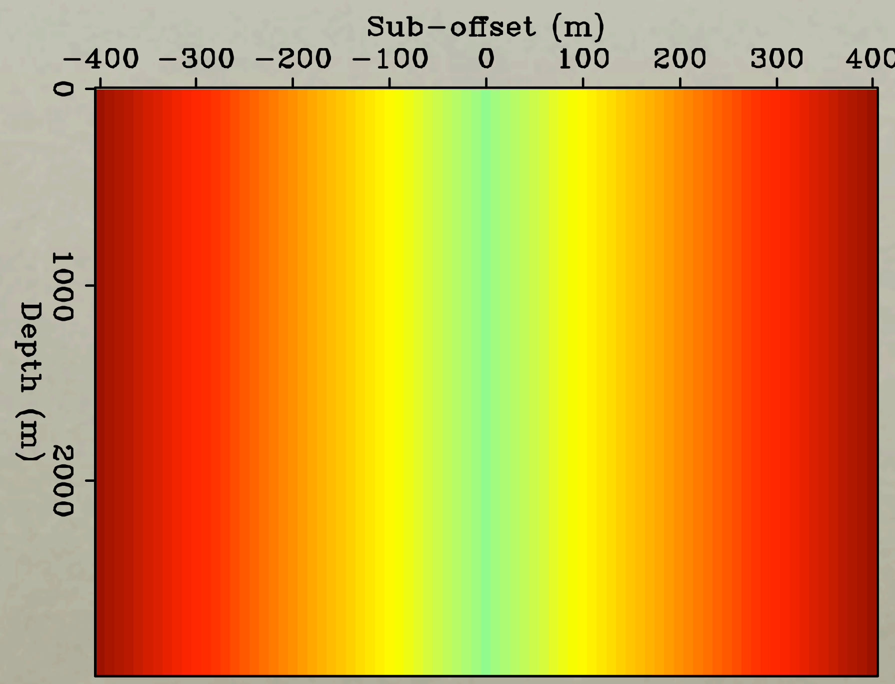


Image-guided weighting function



DSO weighting function

Under-migration

Residual image at azimuth 90°

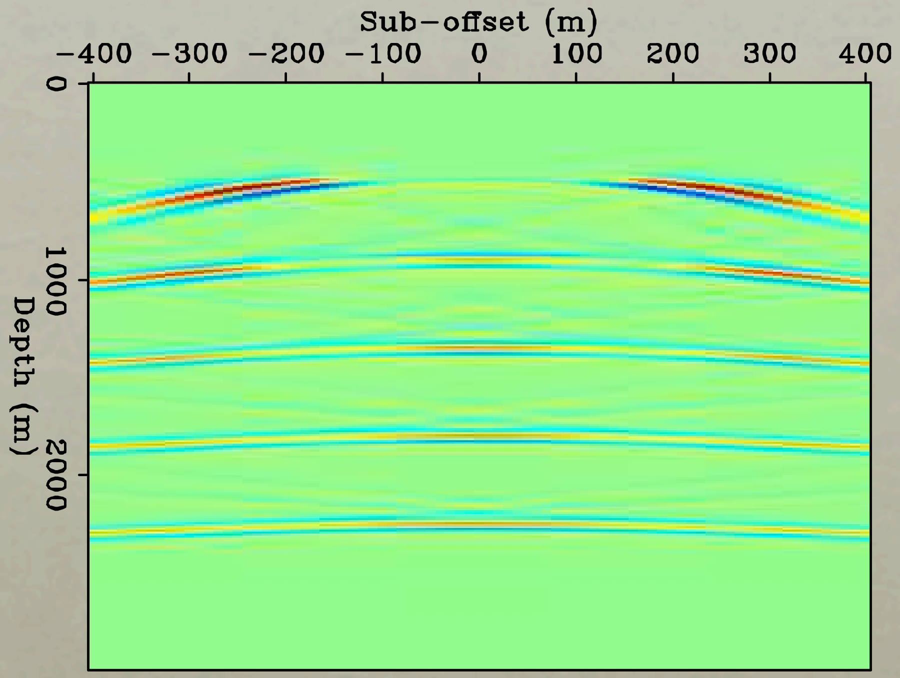
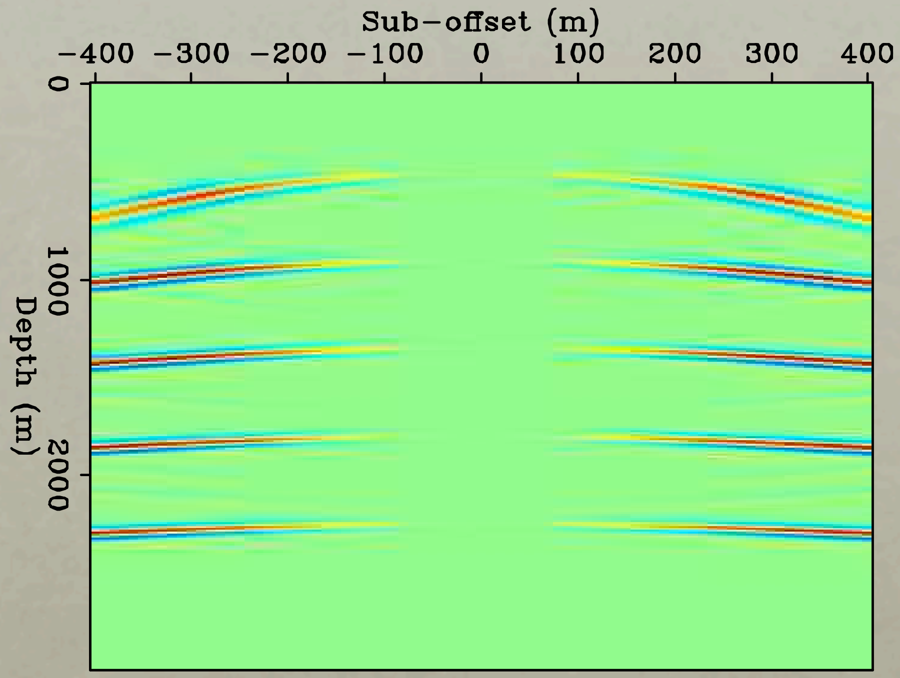


Image-guided weighting function

Residual image at azimuth 90°



DSO weighting function

Under-migration

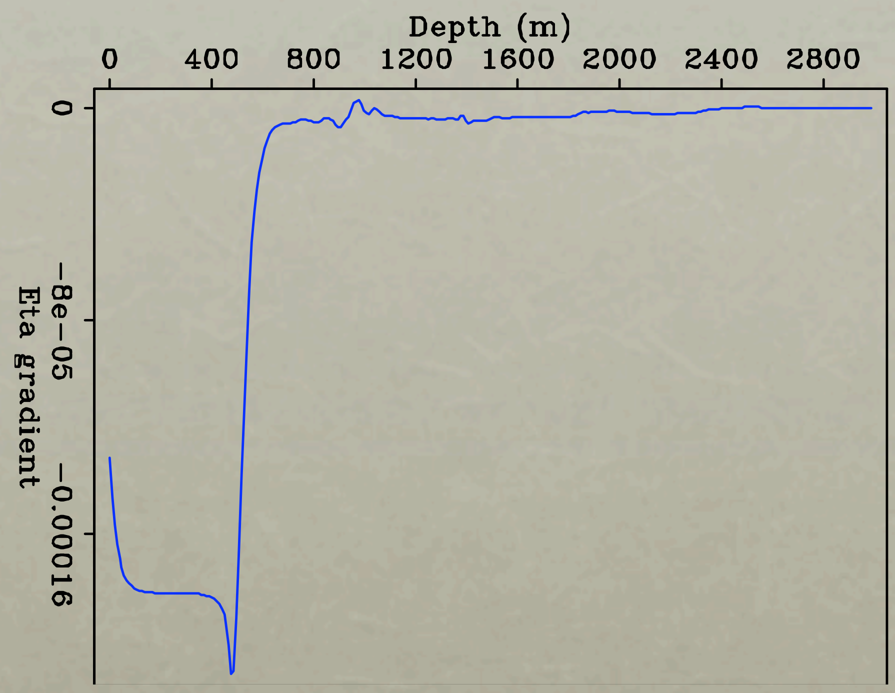
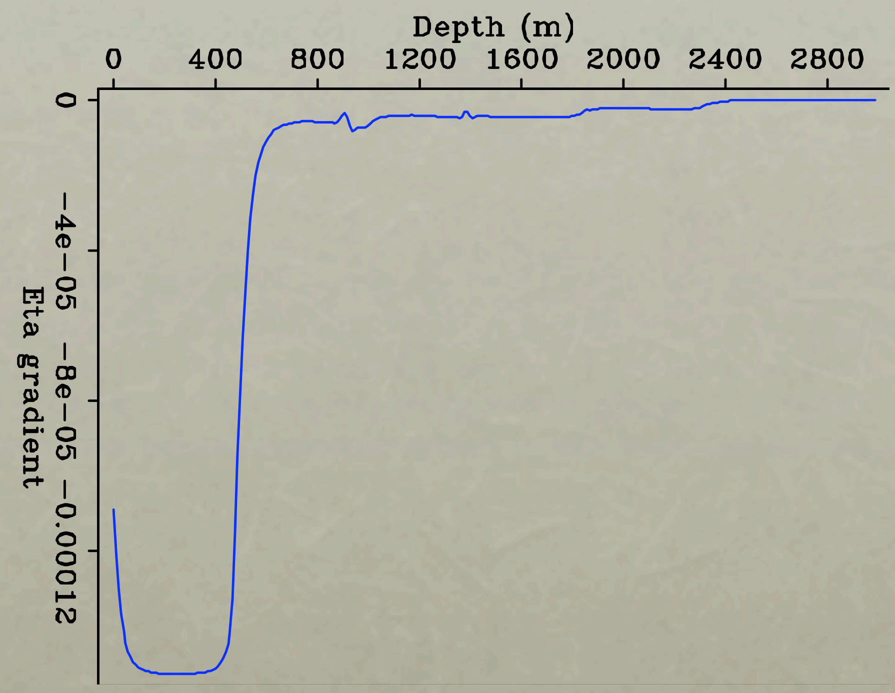


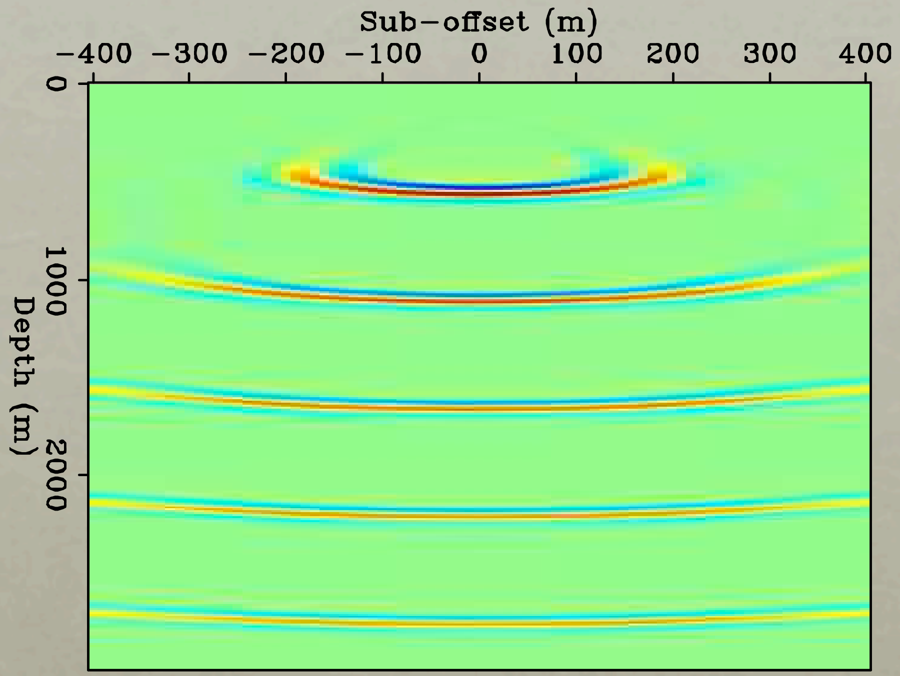
Image-guided weighting function



DSO weighting function

Over-migration

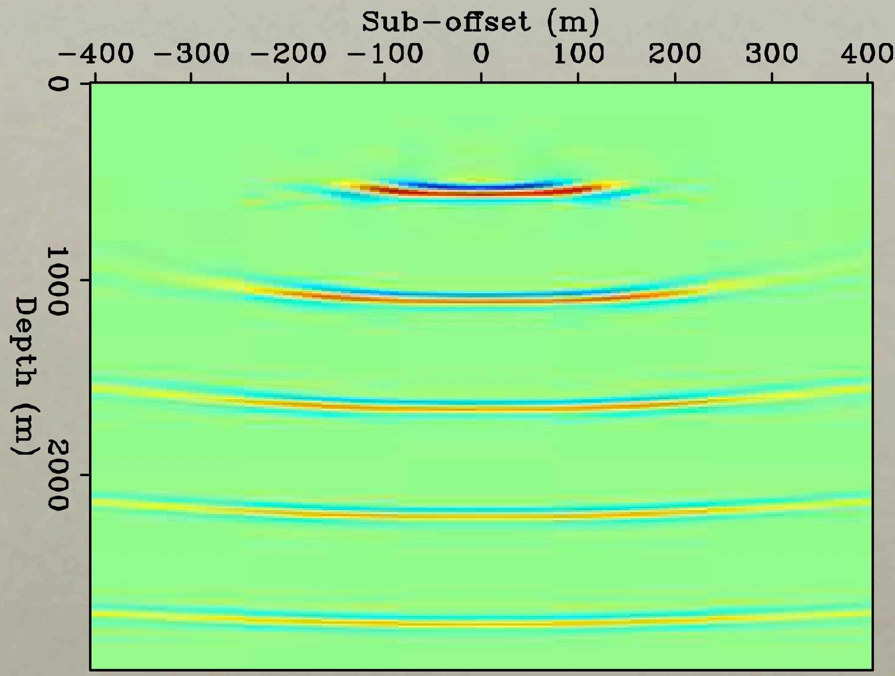
Image at azimuth 0°



$V_{p0_t} = 2000m/s, \eta_t = 0.2, \delta_t = 0.1$

$V_{p0_m} = 2200m/s, \eta_m = 0.2, \delta_m = 0.1$

Image at azimuth 90°



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Over-migration

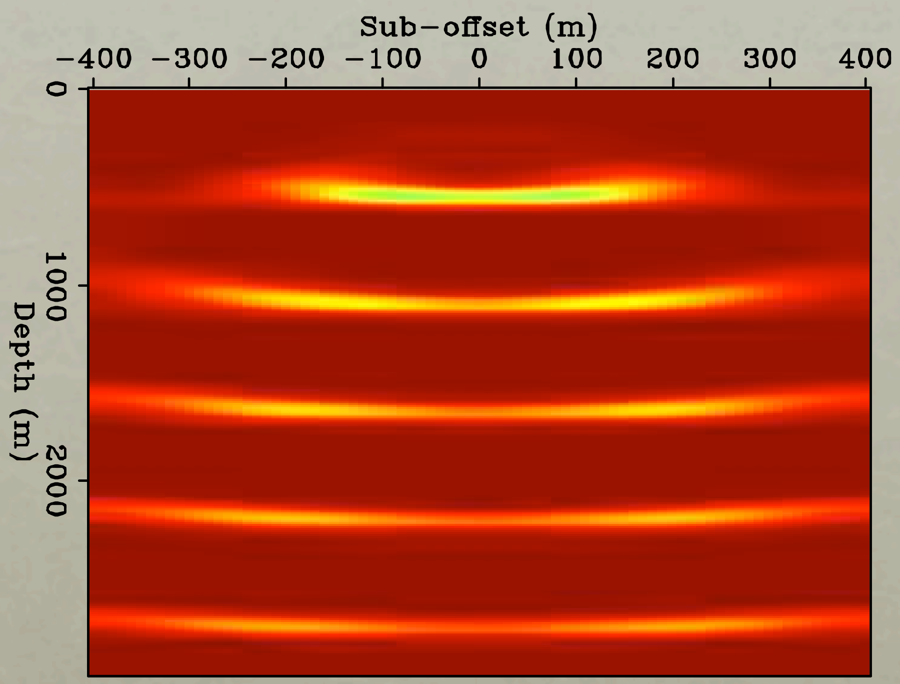
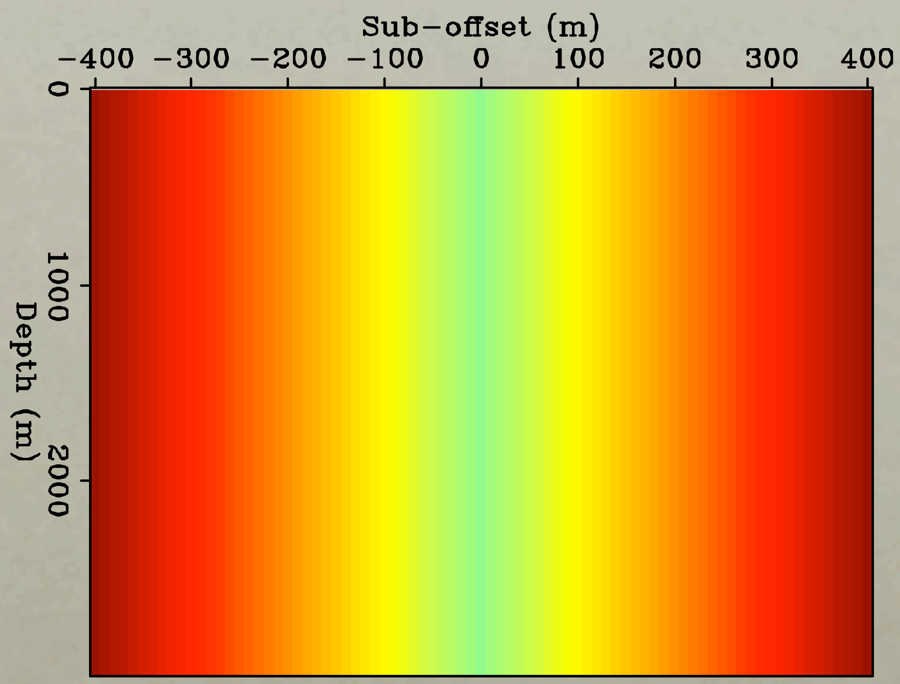


Image-guided weighting function



DSO weighting function

Over-migration

Residual image at azimuth 90°

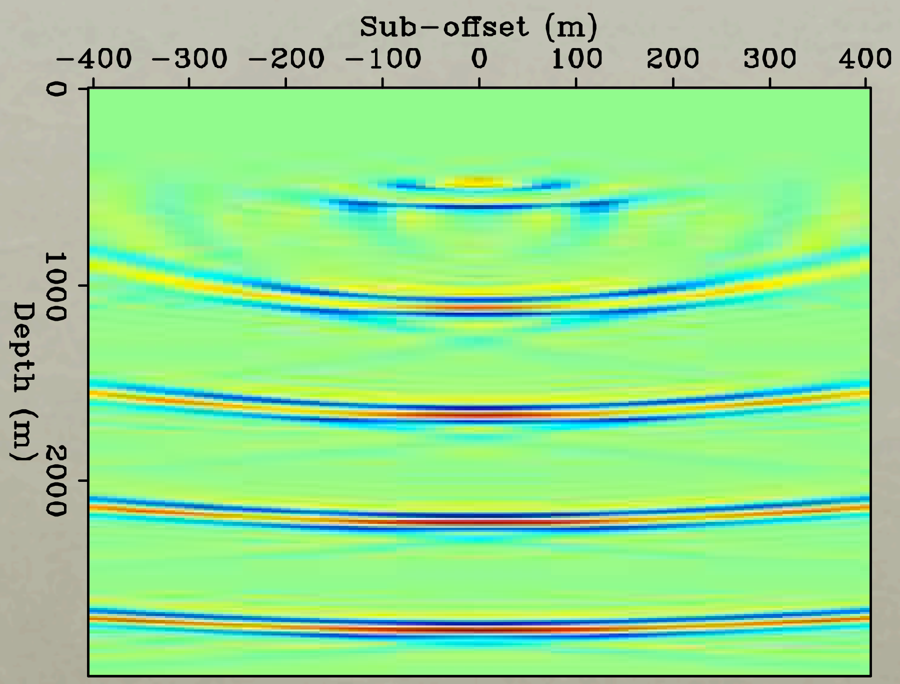
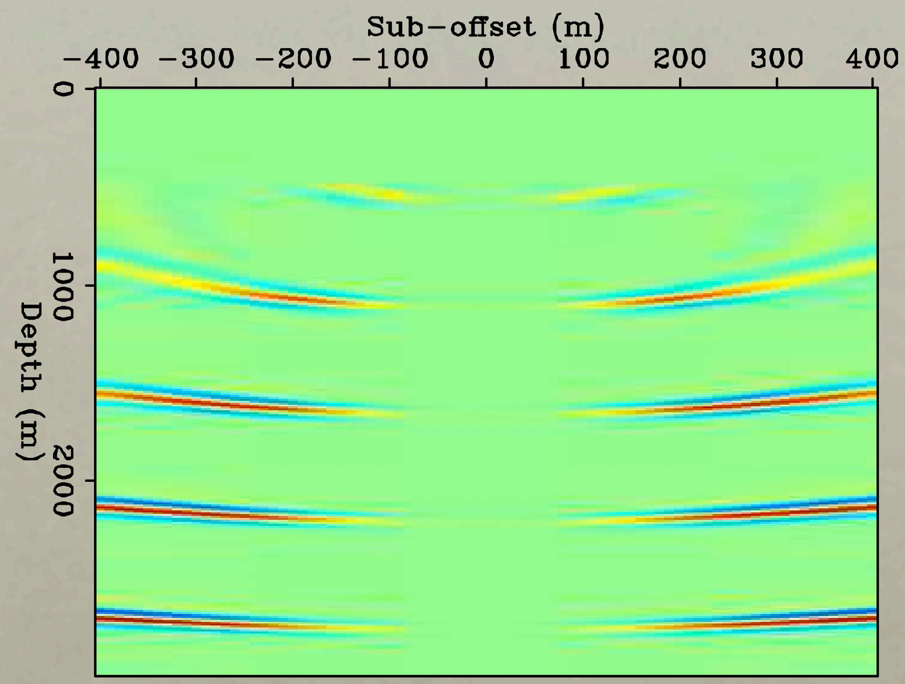


Image-guided weighting function

Residual image at azimuth 90°



DSO weighting function

Over-migration

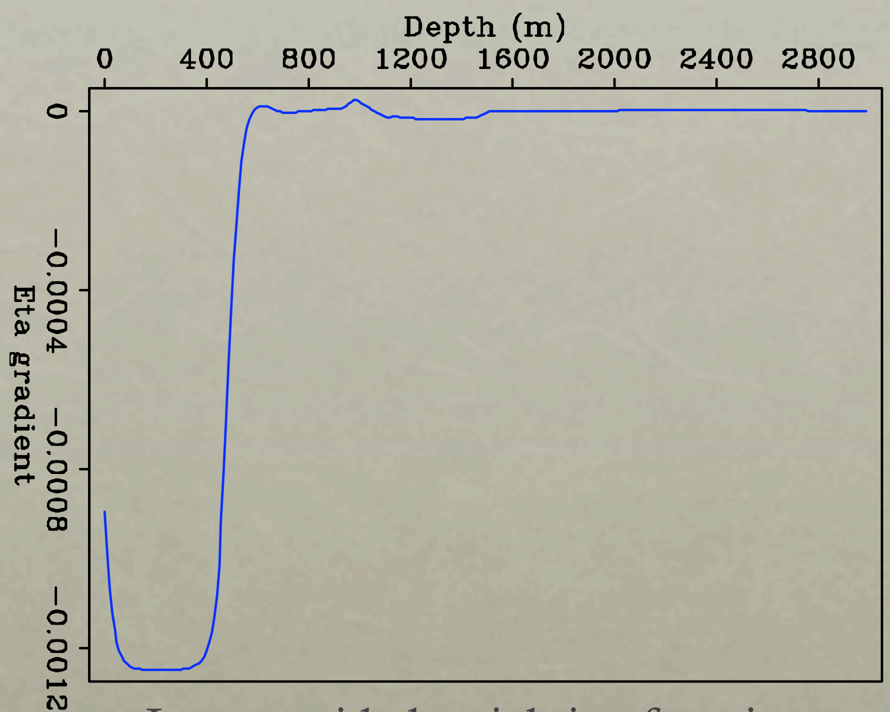
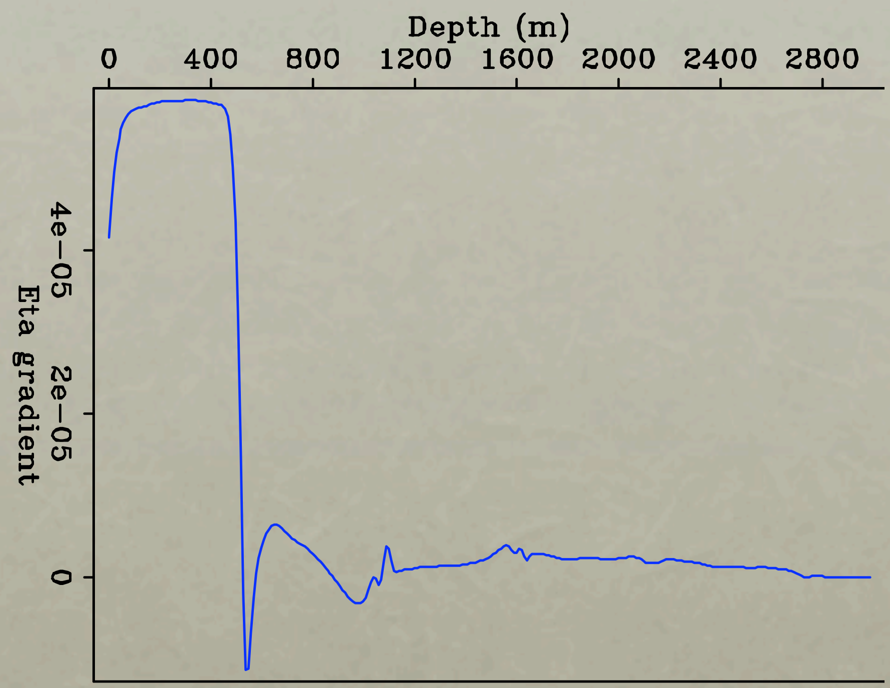
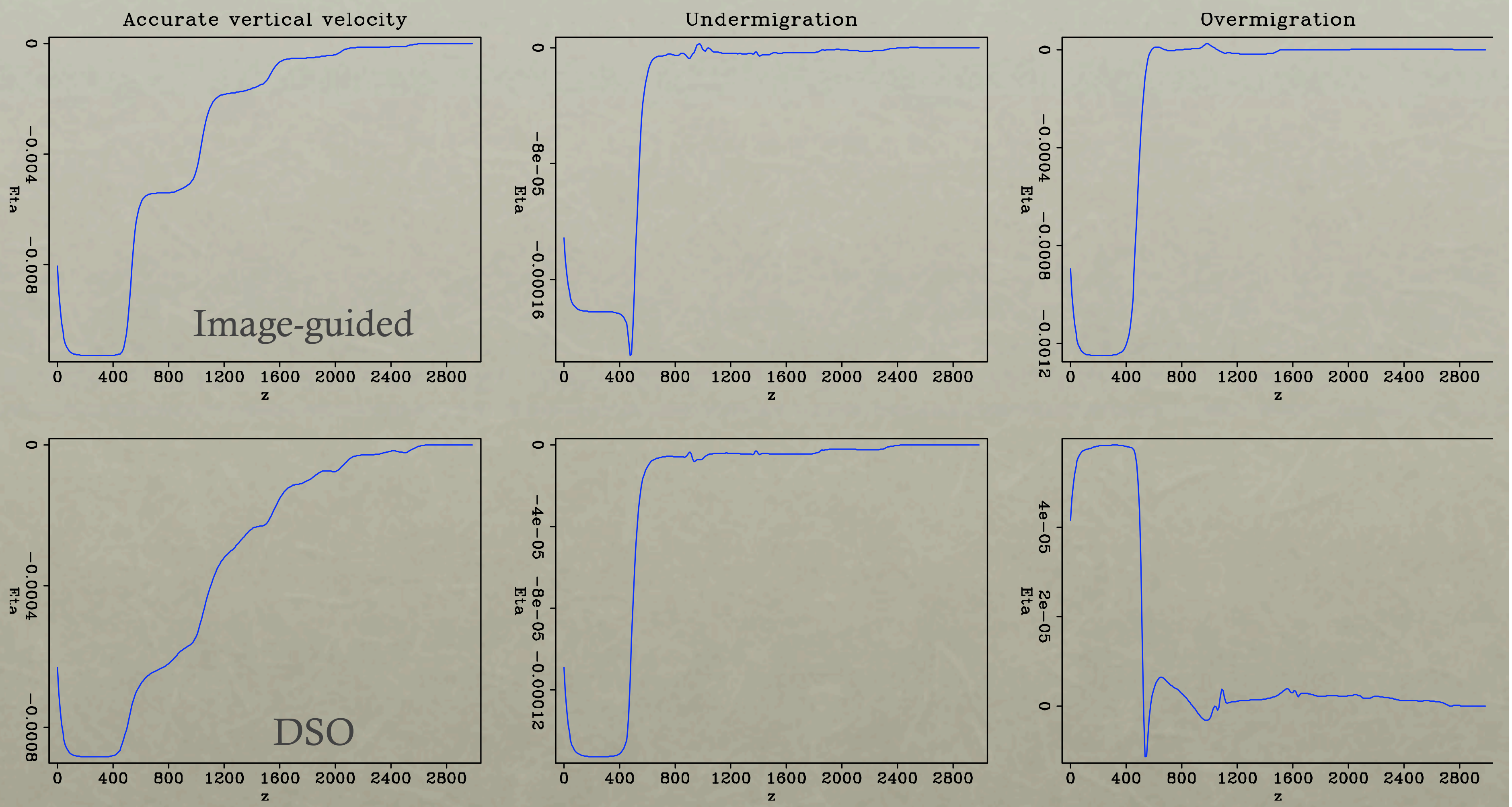


Image-guided weighting function



DSO weighting function

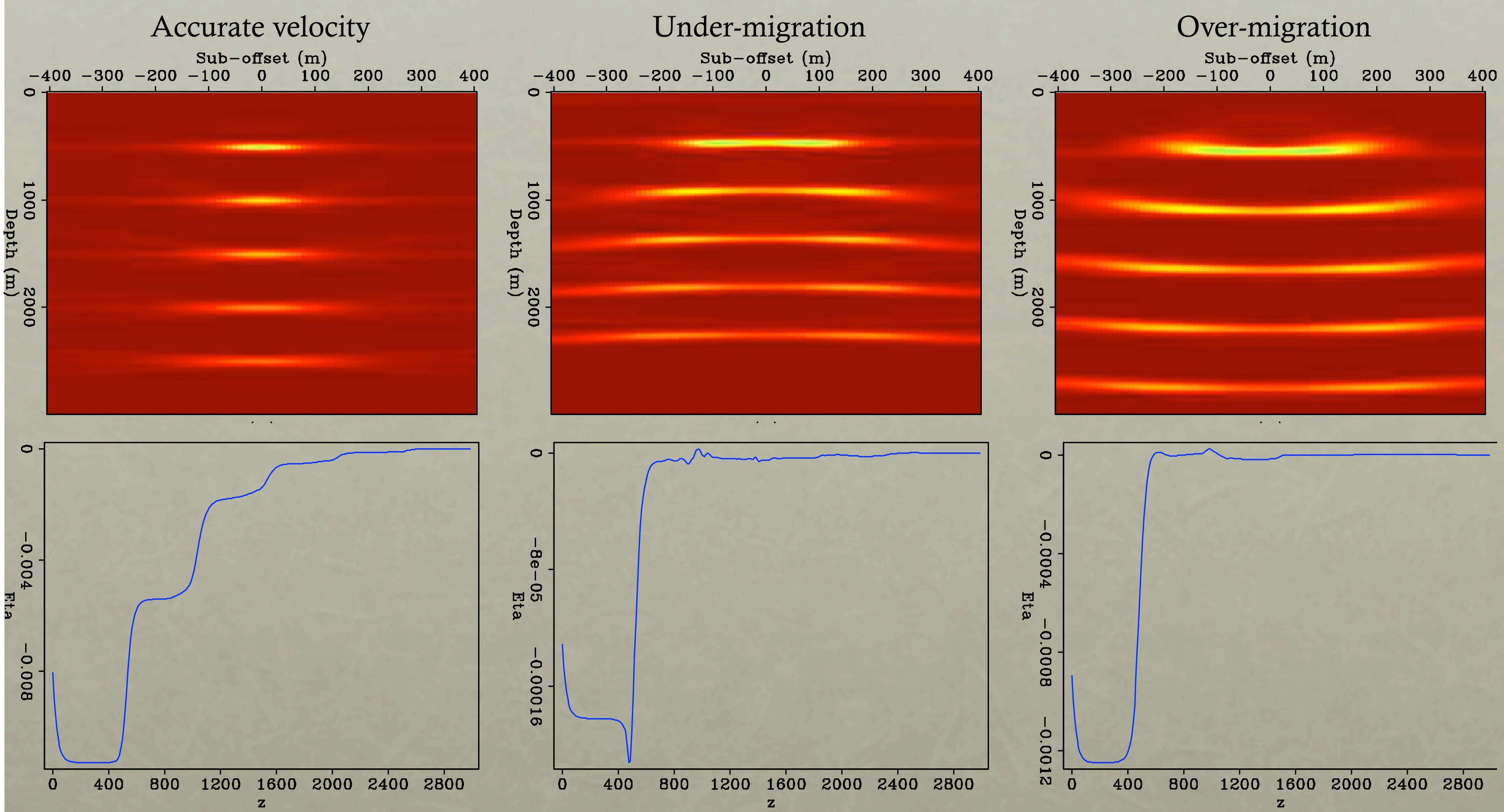
Summary


Accurate vertical velocity
Undermigration
Overmigration
Image-guided
DSO
Eta
z
0
400
800
1200
1600
2000
2400
2800
−0.004
−0.008
−8e−05
−0.00016
−0.0004
−0.0008
−0.0012
−4e−05
−0.00012
4e−05
2e−05

Conclusions

- Image-guided WEMVA produces meaningful updates for orthorhombic anisotropy parameters.
- Image-guided WEMVA can separate the kinematics error due to the errors in velocity and anisotropic parameters.

Thank you!



Accurate velocity
Under-migration
Over-migration
Sub−offset (m)
−400 −300 −200 −100 0 100 200 300 400
Depth (m)
0
1000
2000
Eta
0
−0.004
−0.008
−8e−05
−0.00016
−0.0004
−0.0008
−0.0012
0 400 800 1200 1600 2000 2400 2800
z