Enhancement of velocity field estimation by Common Scatter Point (CSP) gathers

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CREWES sponsors meeting 2010
December,03,2010

CREWES

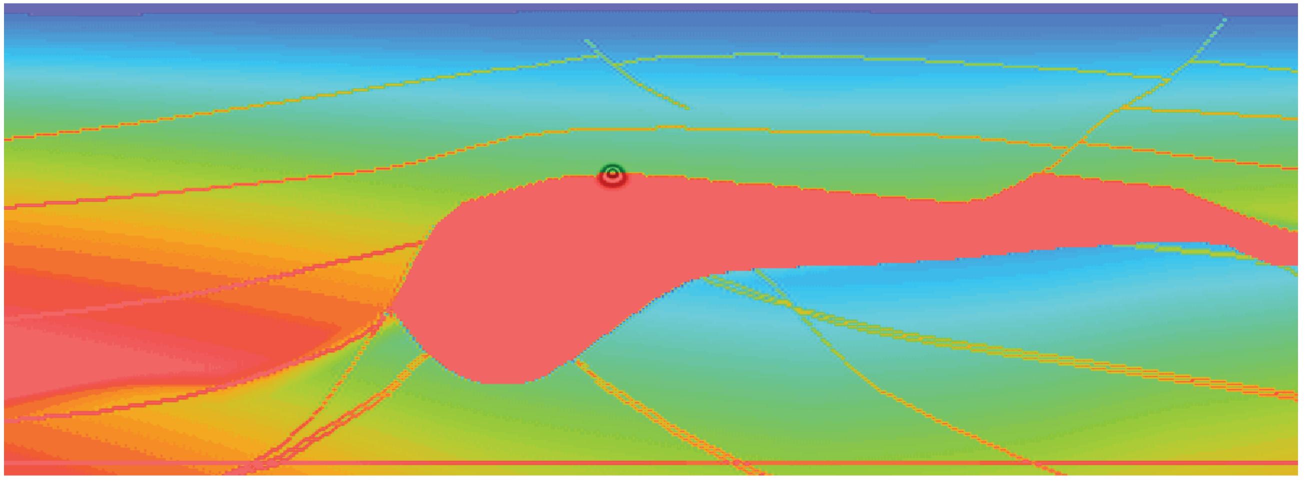
Consortium for Research in Elastic Wave Exploration Seismology

UNIVERSITY OF CALGARY

Outlines

- Introduction to CSP gathers
- Linear time shifts (tilt) on CSP gathers
- Tilt problems for velocity inversion
- solutions
- examples
- Acknowledgments

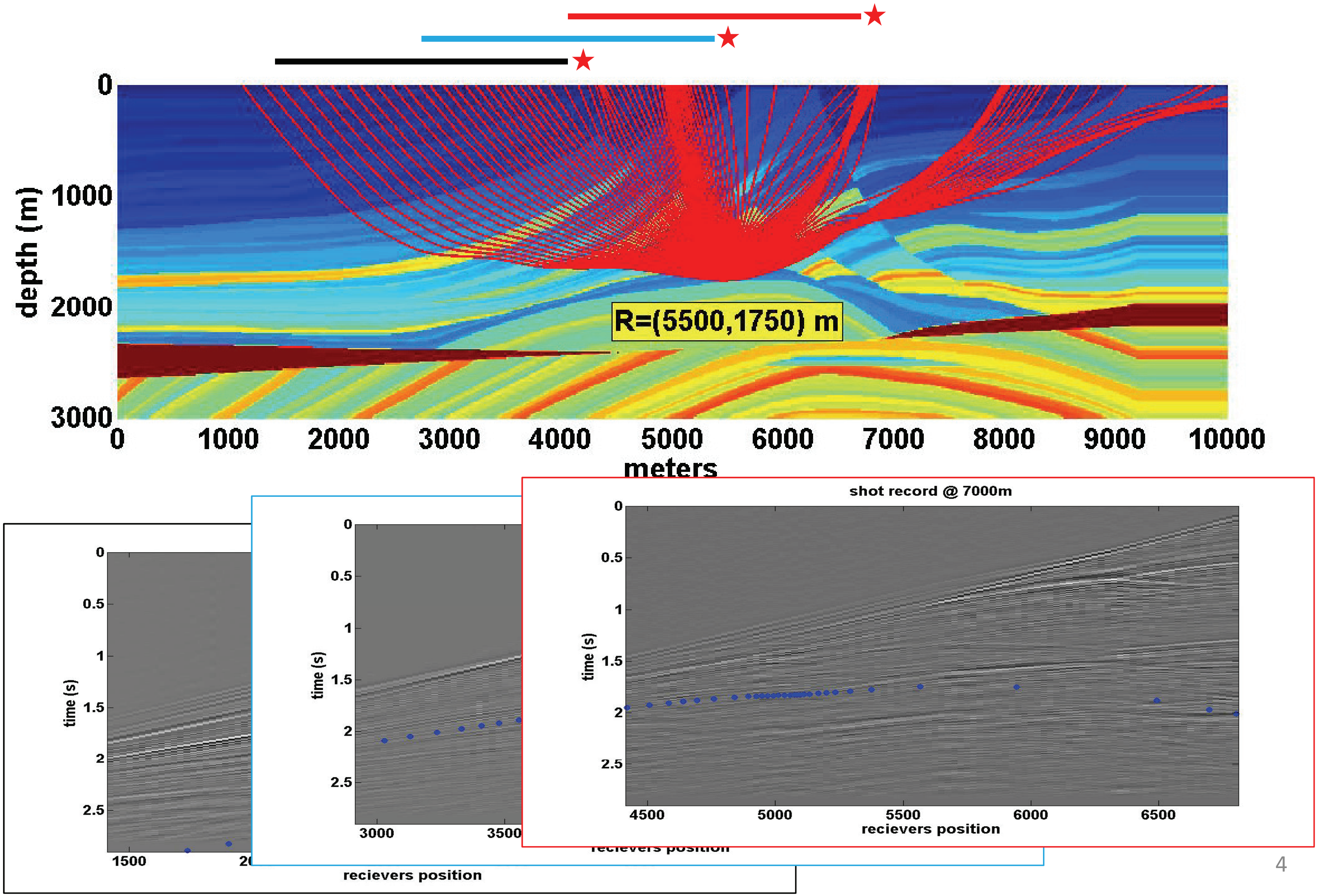
Introduction



"3D Seismic Imaging" by Biondo L. (Biondi SEG publication)

- Scatterpoint
- Huygens principle: an organized arrangement of scatterpoint produce a coherent reflection event.
- Kirchhoff migration

Single scatter point

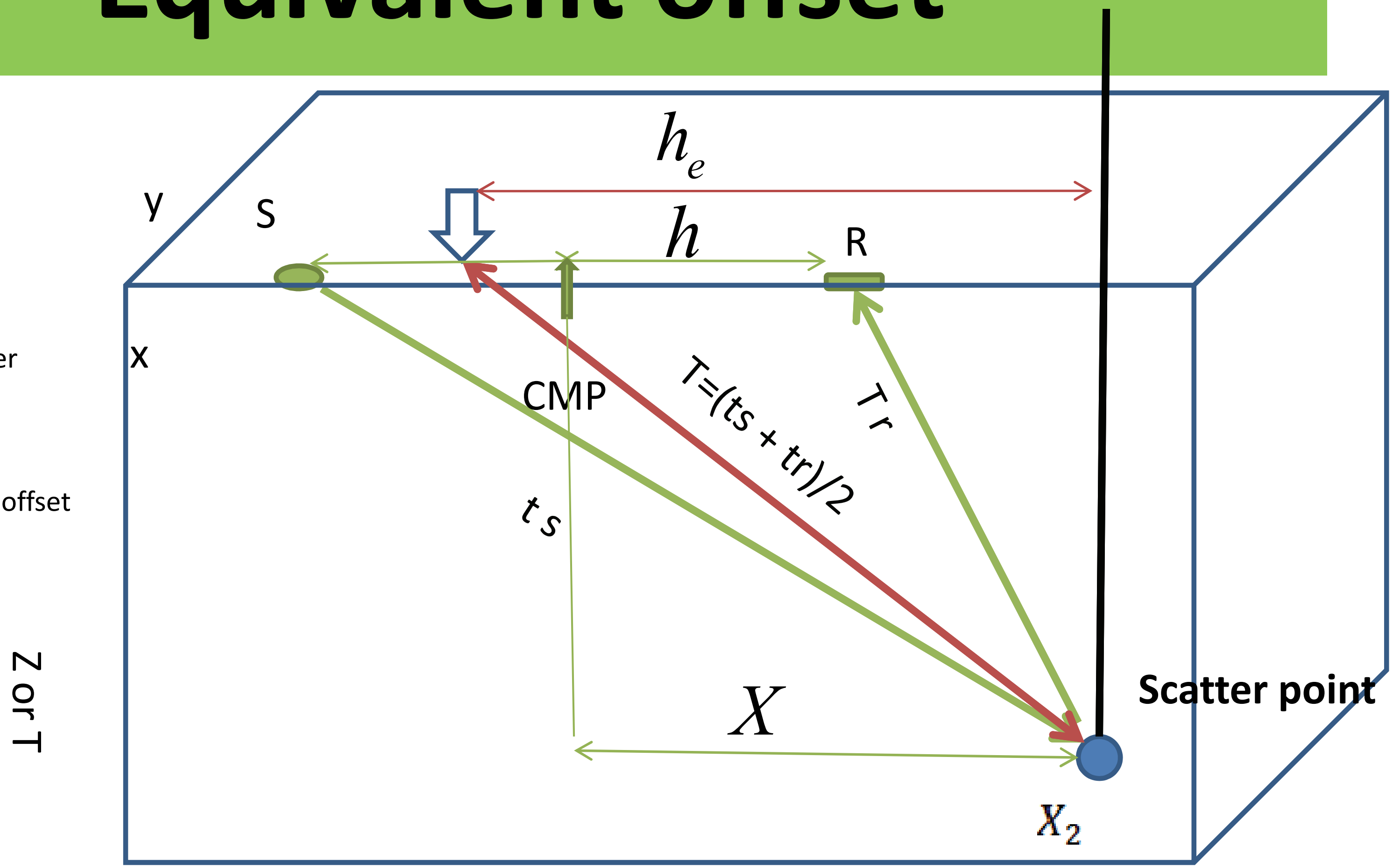


Equivalent offset

X= Distance between scatter point and CMP

h=Half Source and reciever offset

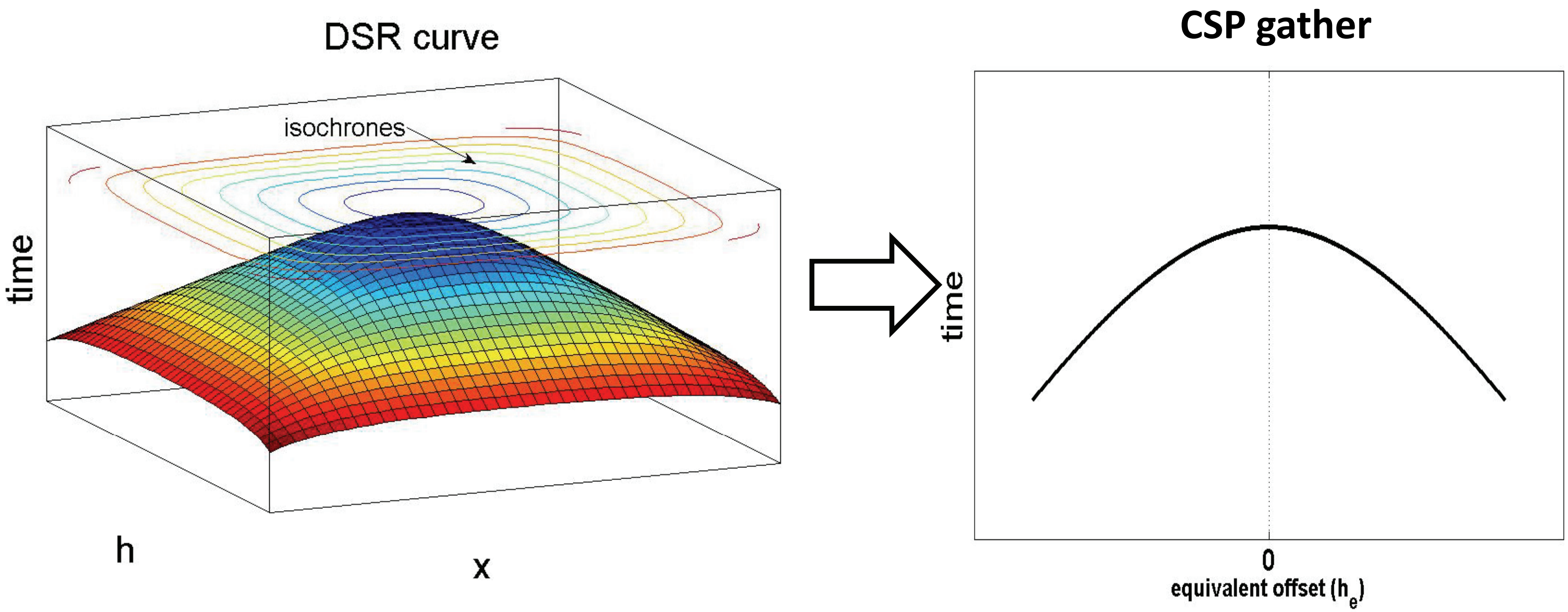
h_e **=**Equivalent offset



$$T = \sqrt{\frac{T_0^2}{4} + \frac{(X+h)^2}{V_{rms}^2}} + \sqrt{\frac{T_0^2}{4} + \frac{(X-h)^2}{V_{rms}^2}} = 2\sqrt{\frac{T_0^2}{4} + \frac{h_e^2}{V_{rms}^2}} \Leftrightarrow h_e^2 = X^2 + h^2 - \left(\frac{2Xh}{TV_{rms}}\right)^2$$

(Bancroft et al,1996)

CSP gather

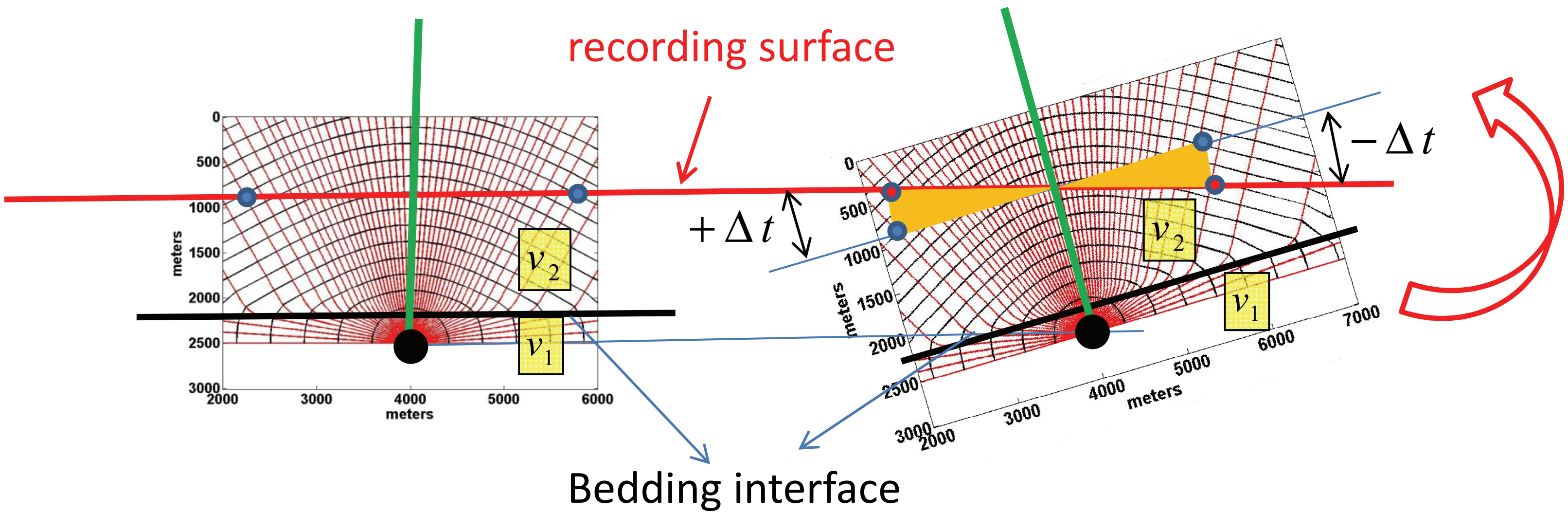


X= Distance between scatterpoint and S/R CMP

h=Half S/R offset

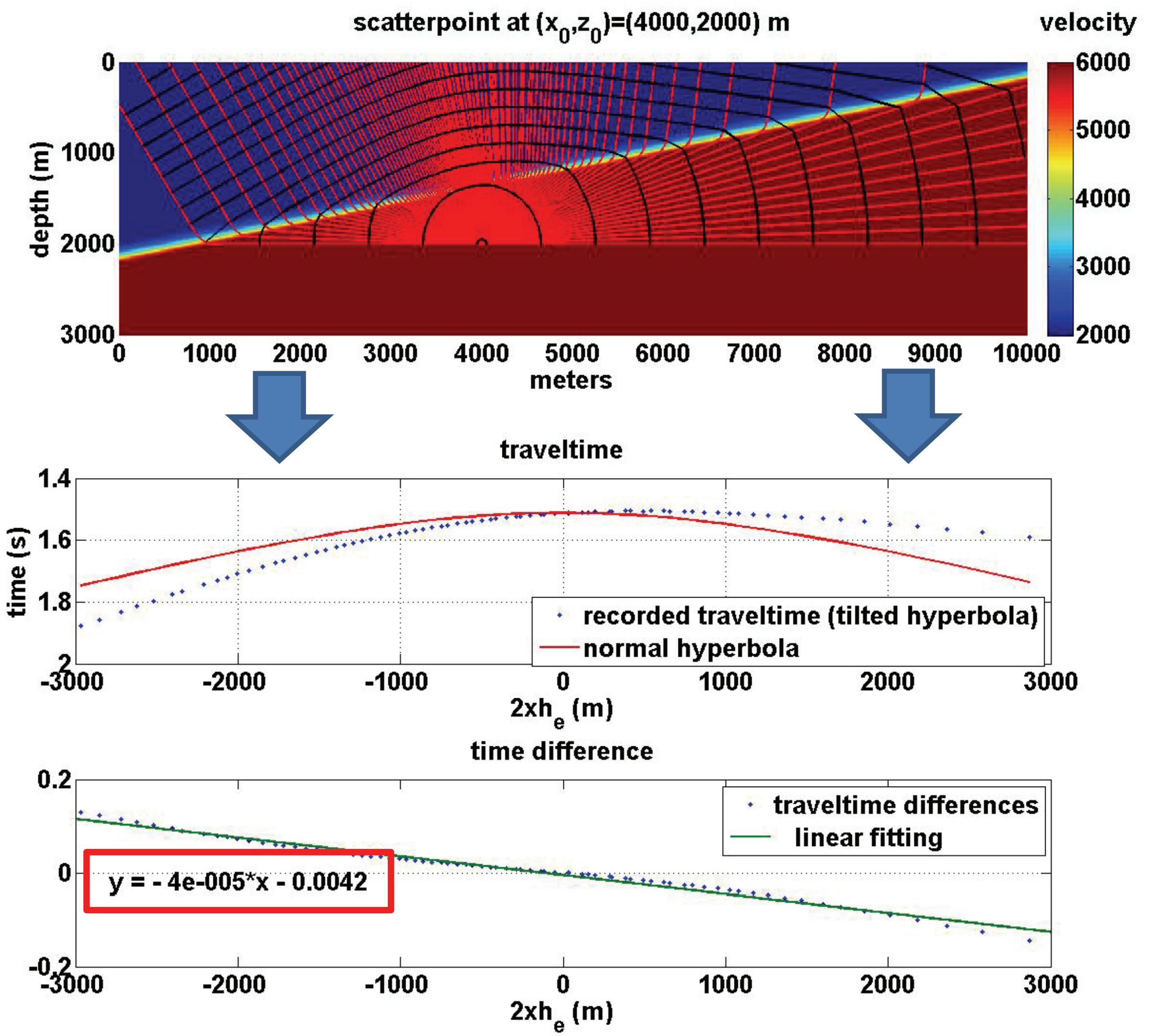
$$t(S,G) = \sqrt{t_0^{\,2} + \left(\frac{2h_e}{v_m}\right)^2}$$

Hyperbola tilt

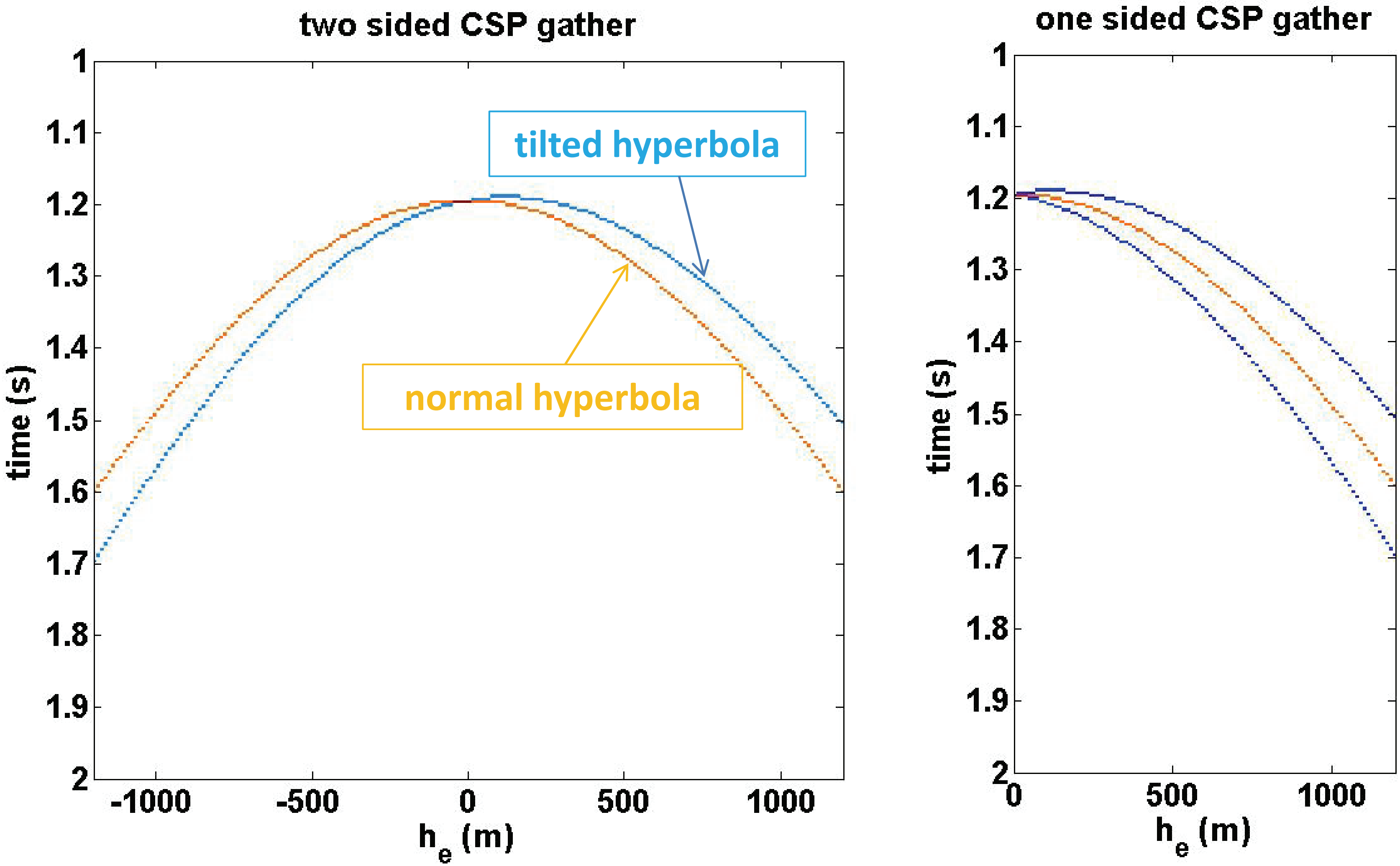


$$t_{tilted} \approx t_{normal} + h_e \alpha$$

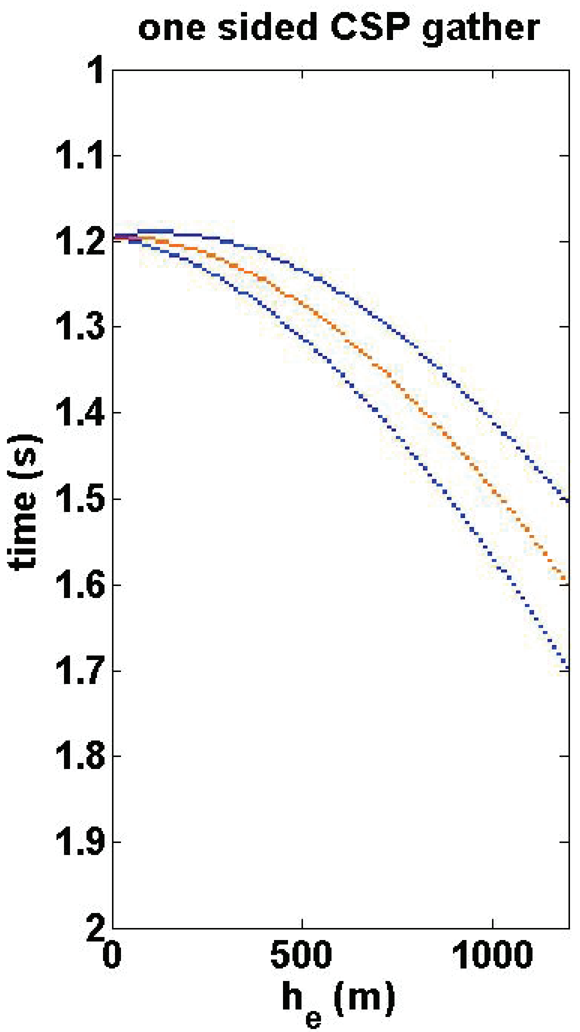
Principles of linear time shift

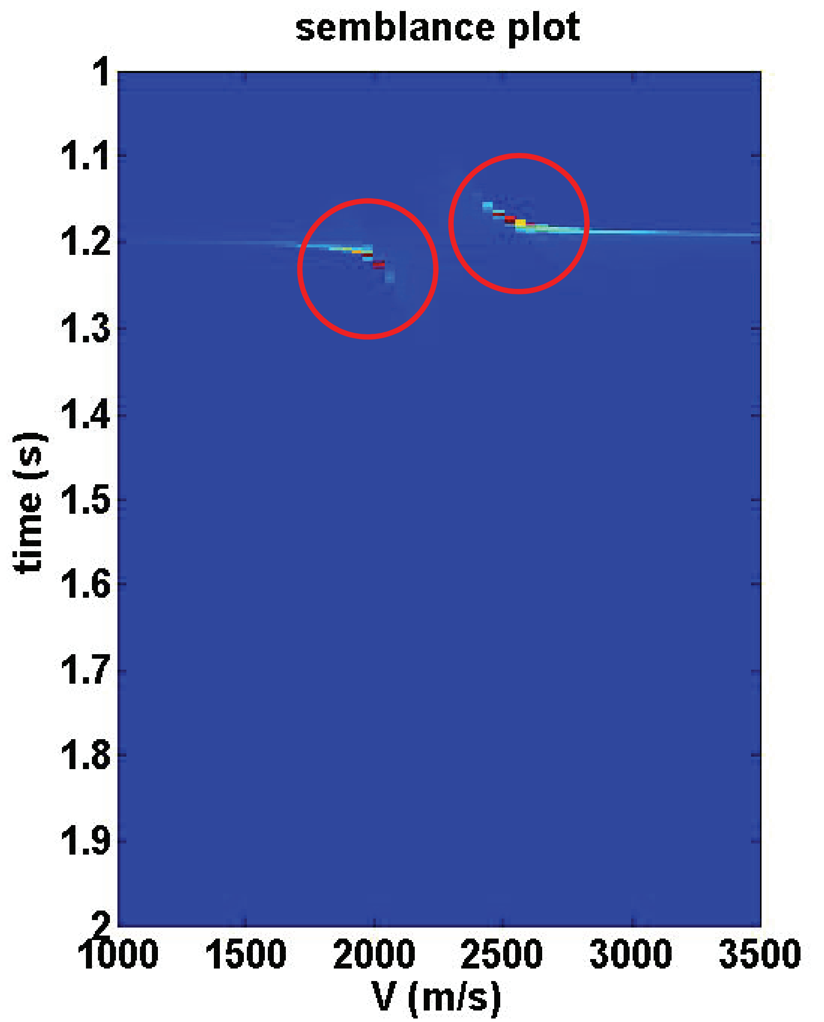


Tilt problem in velocity inversion

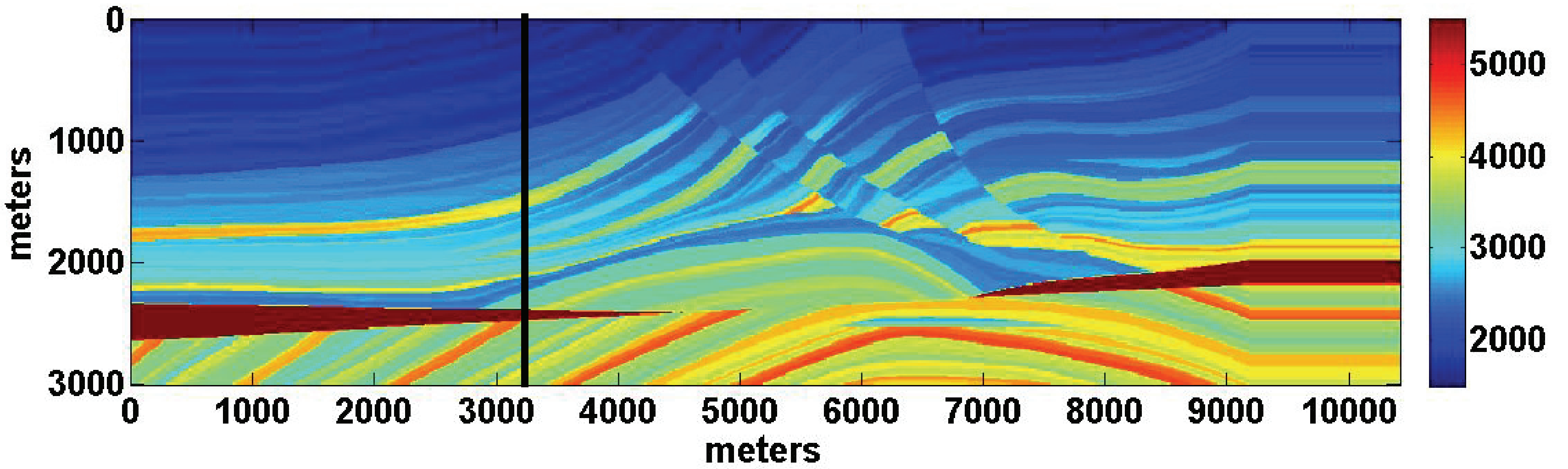


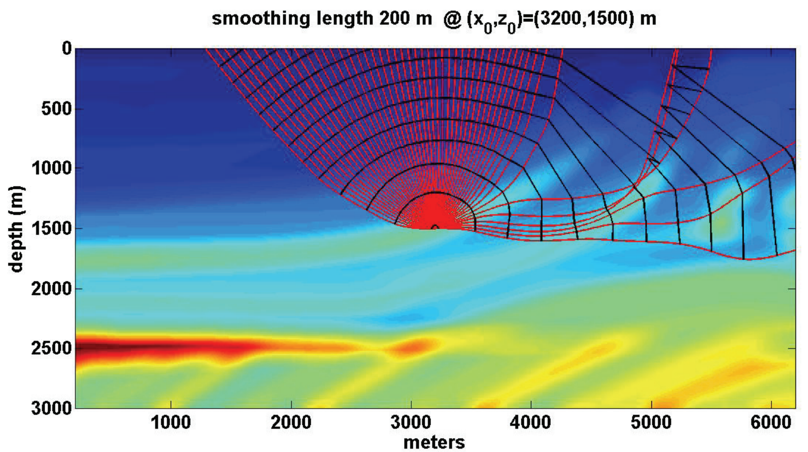
Tilt problem in velocity inversion



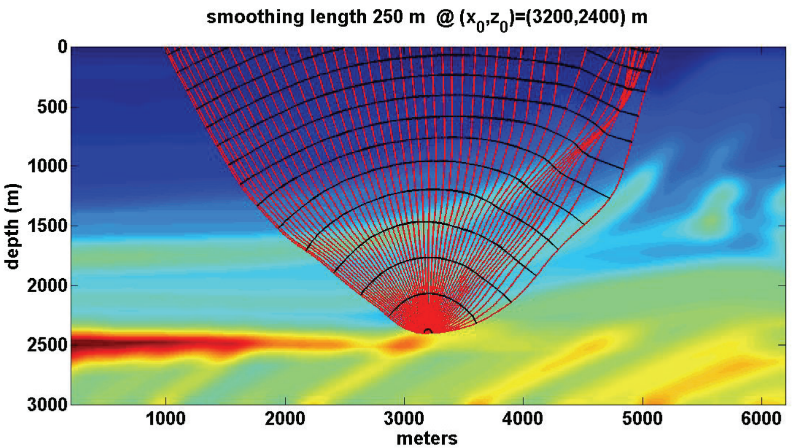


Marmousi example



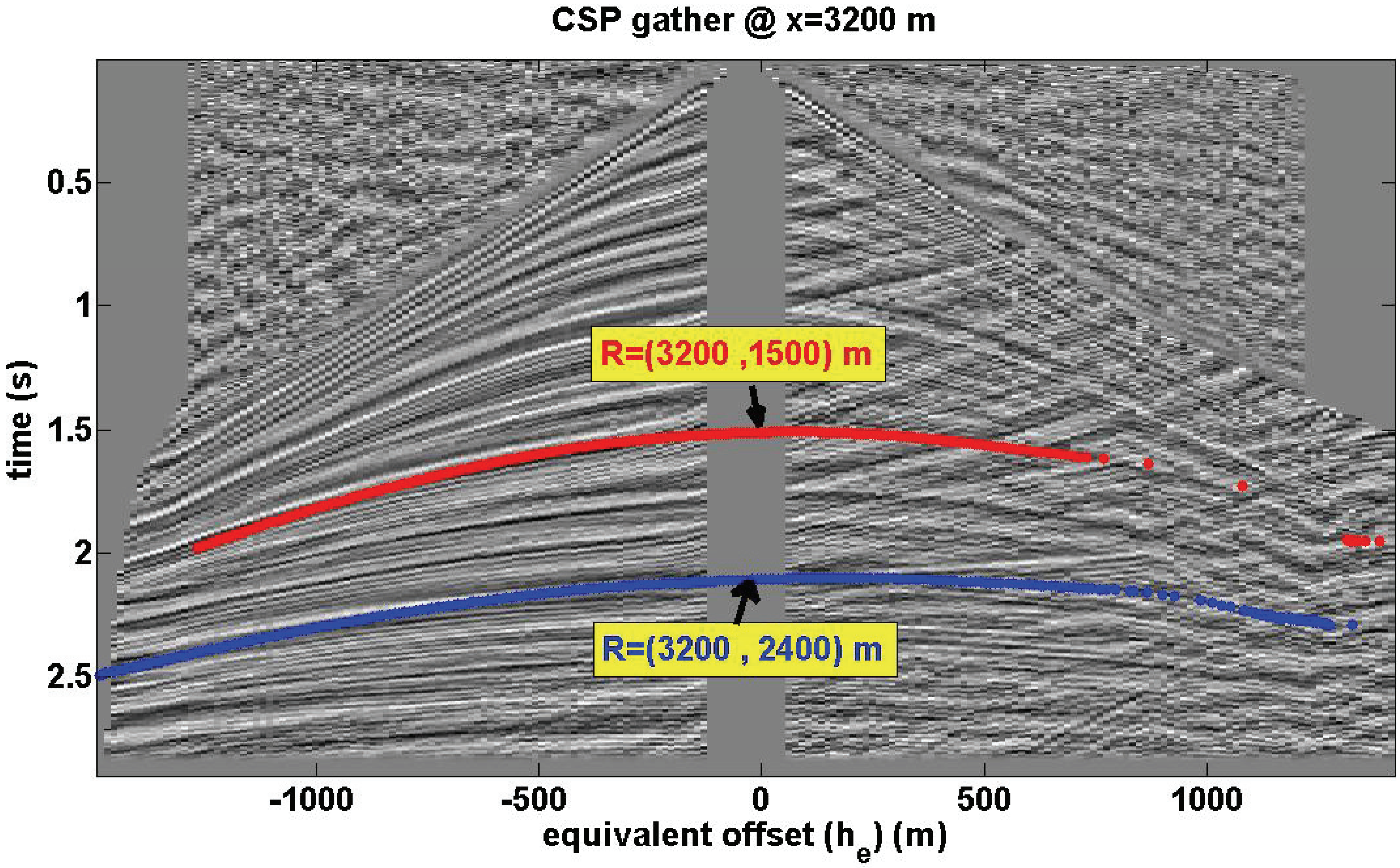


Scatterpoint A

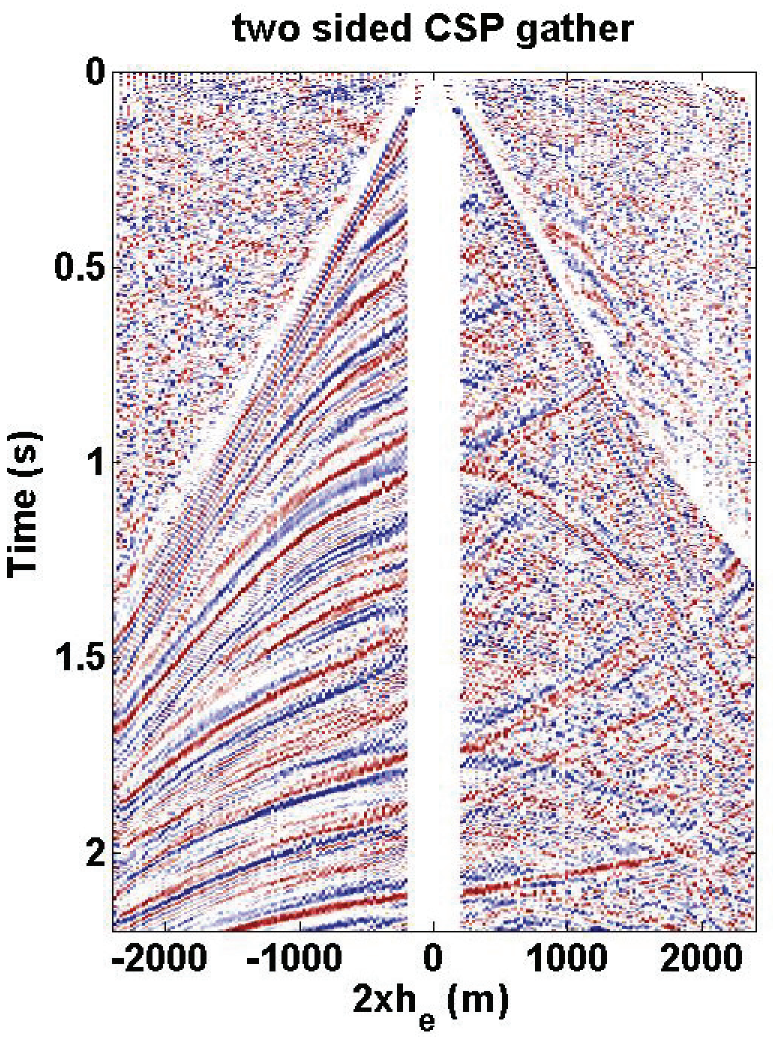


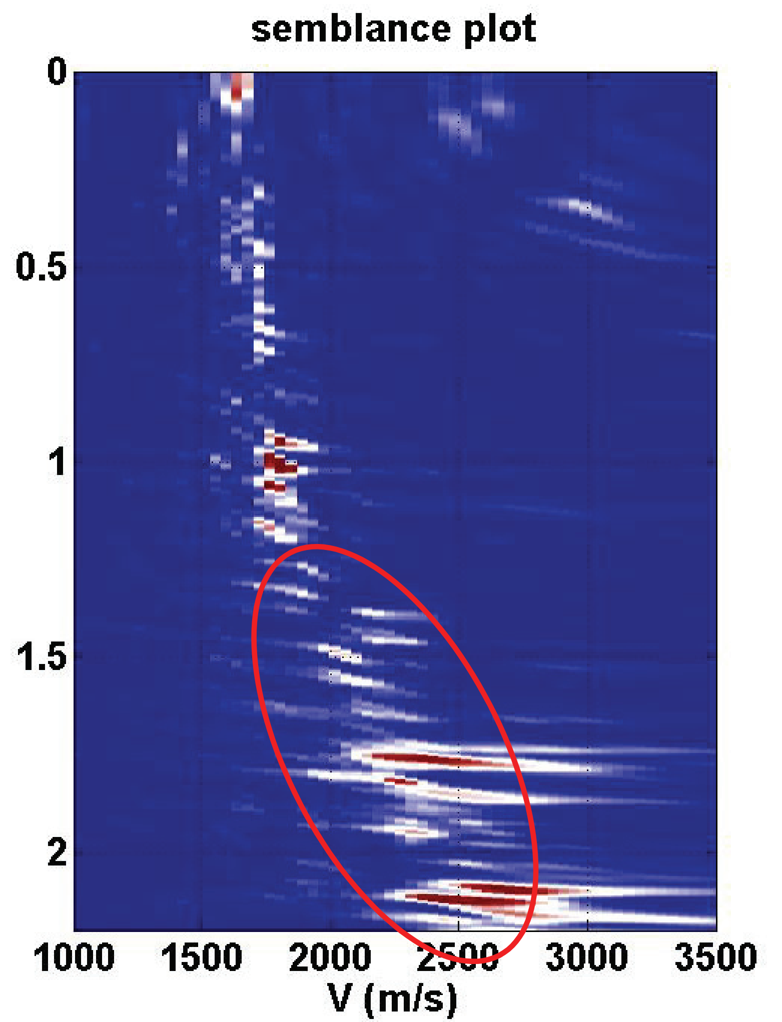
Scatterpoint B

CSP modeling

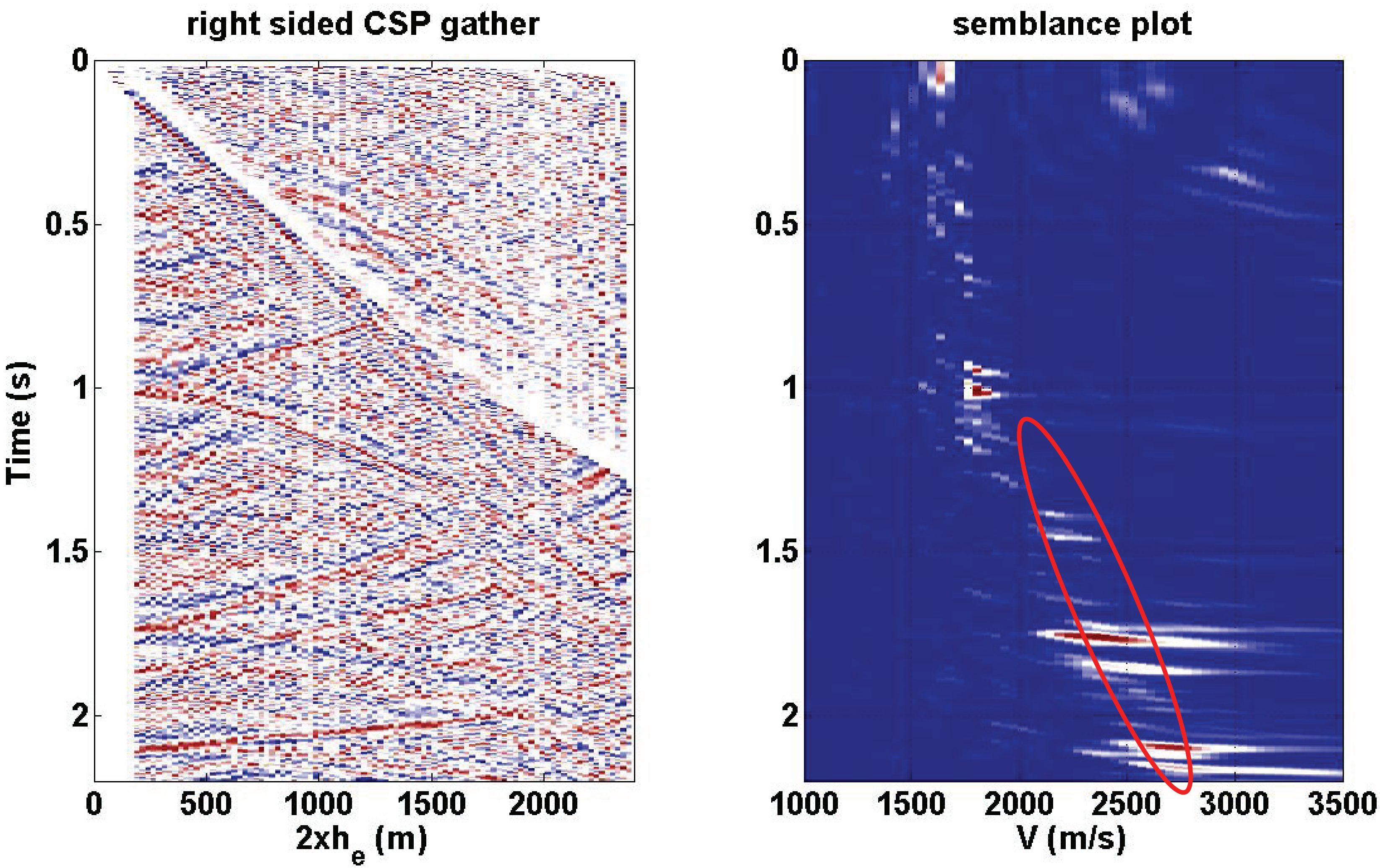


Semblance analysis

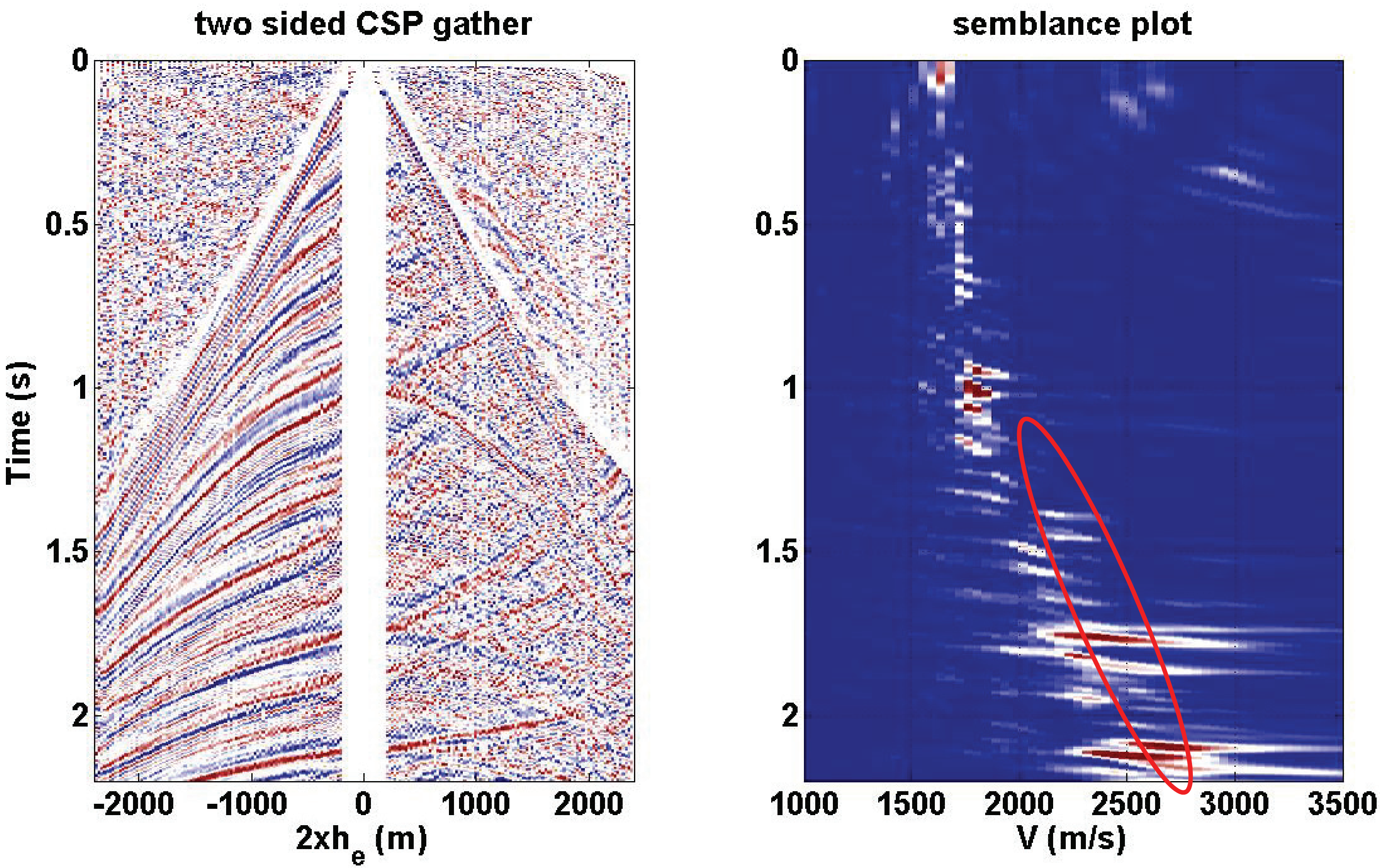




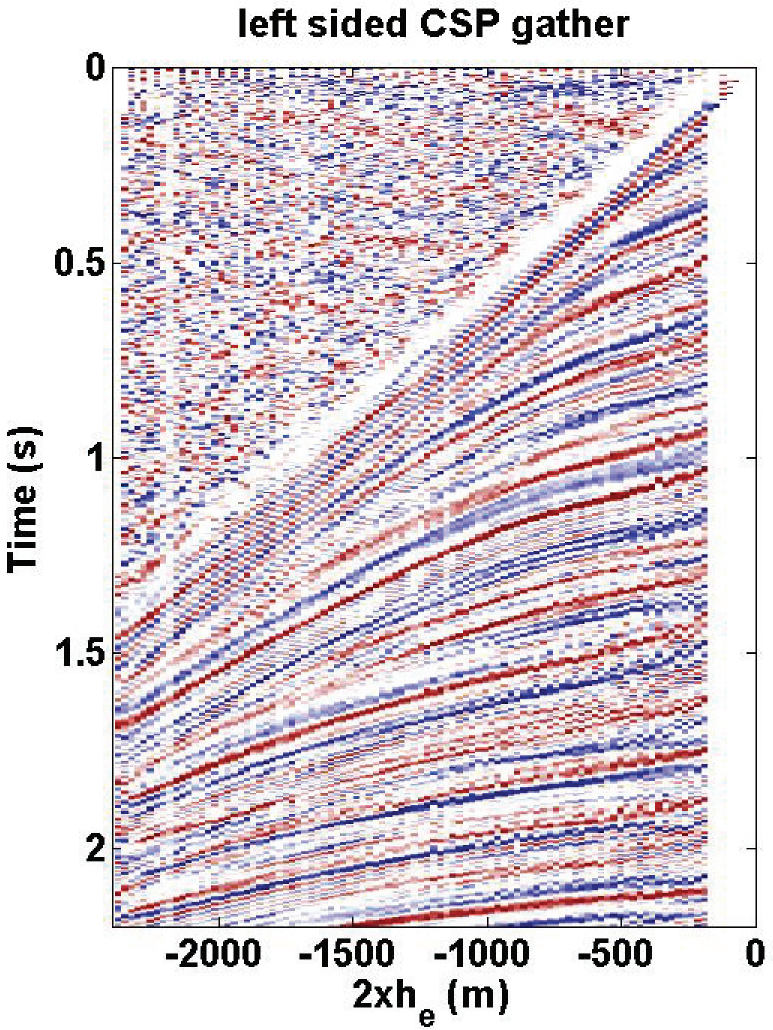
Semblance analysis

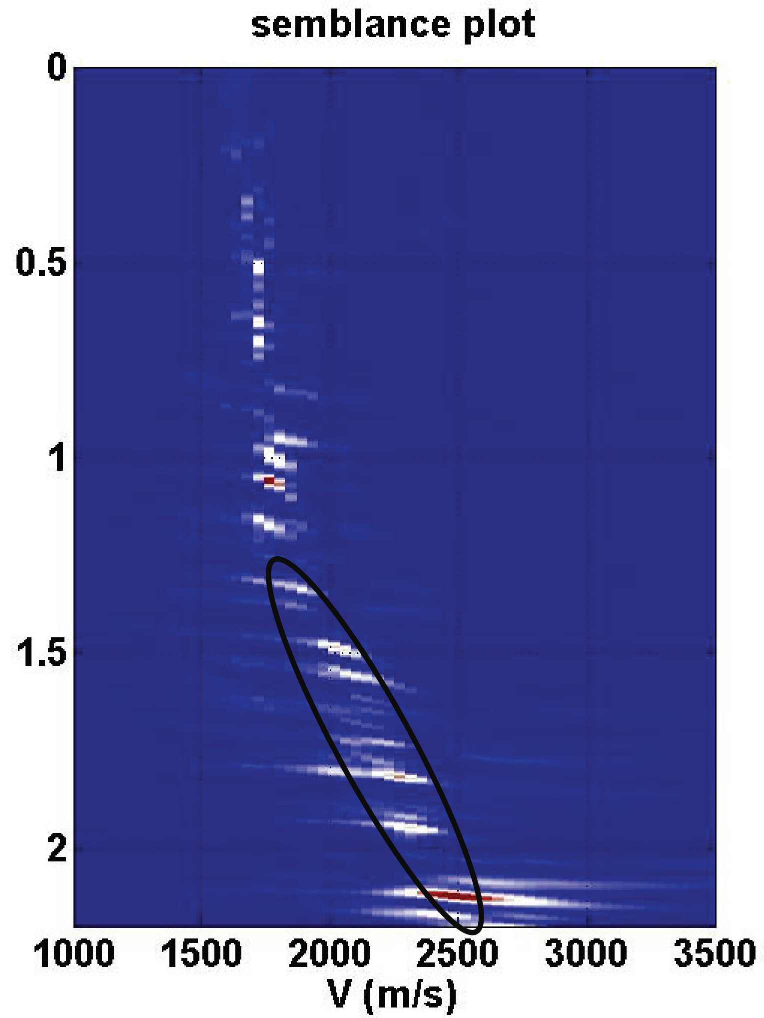


Semblance analysis

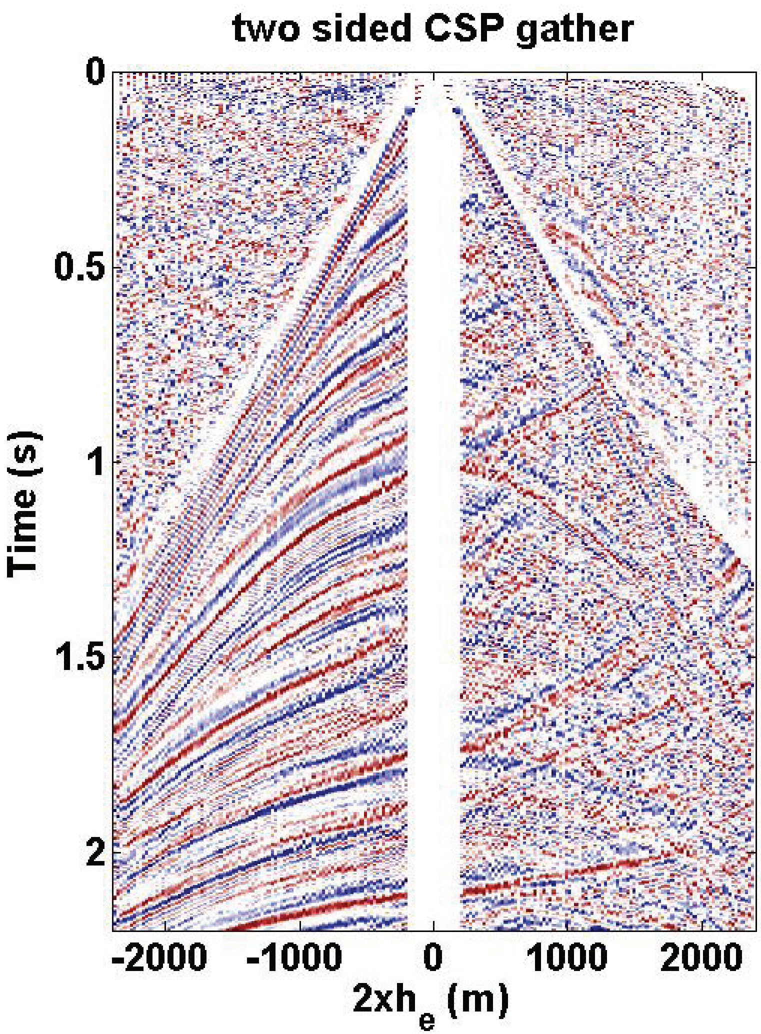


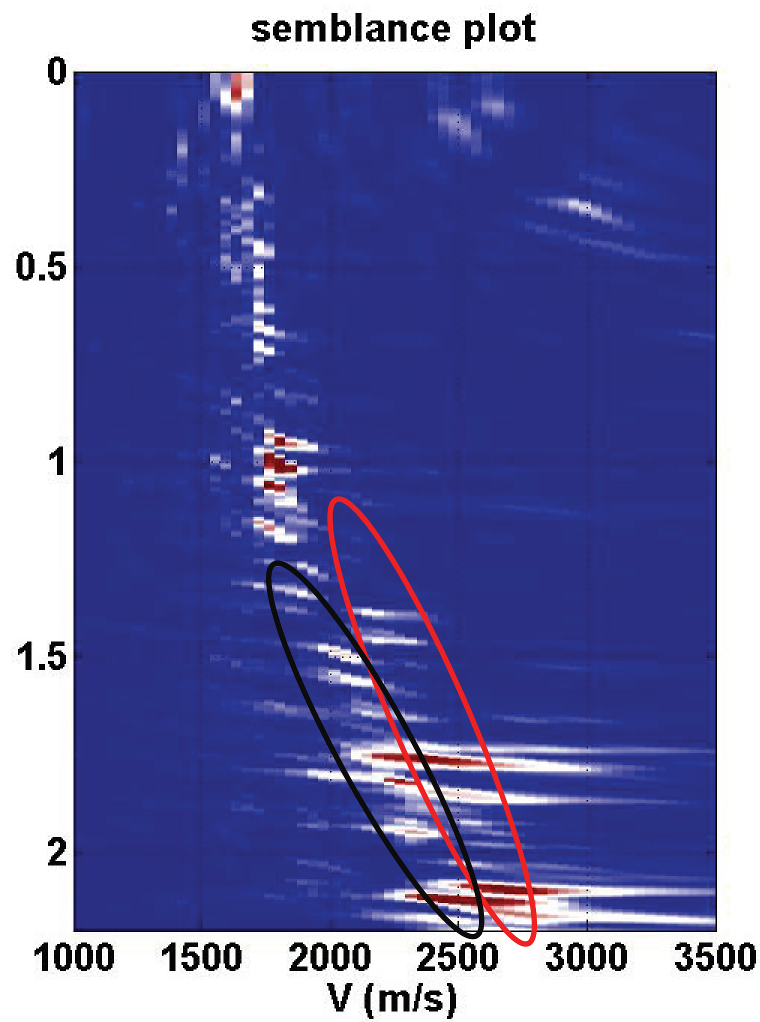
Semblance analysis





Semblance analysis





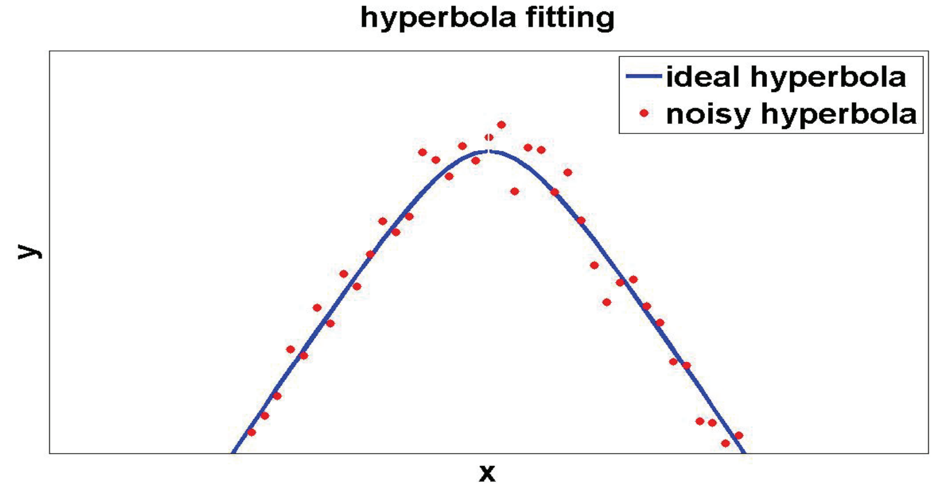
Hyperbola least squares fitting

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$$

given n points

(x_i, y_i) ⇨

$$\begin{aligned} Ax_1^2 + Bx_1y_1 + Cy_1^2 + Dx_1 + Ey_1 + F &= r_1 \\ \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad &\vdots \\ Ax_n^2 + Bx_ny_n + Cy_n^2 + Dx_n + Ey_n + F &= r_n \end{aligned}$$



Hyperbola least squares fitting

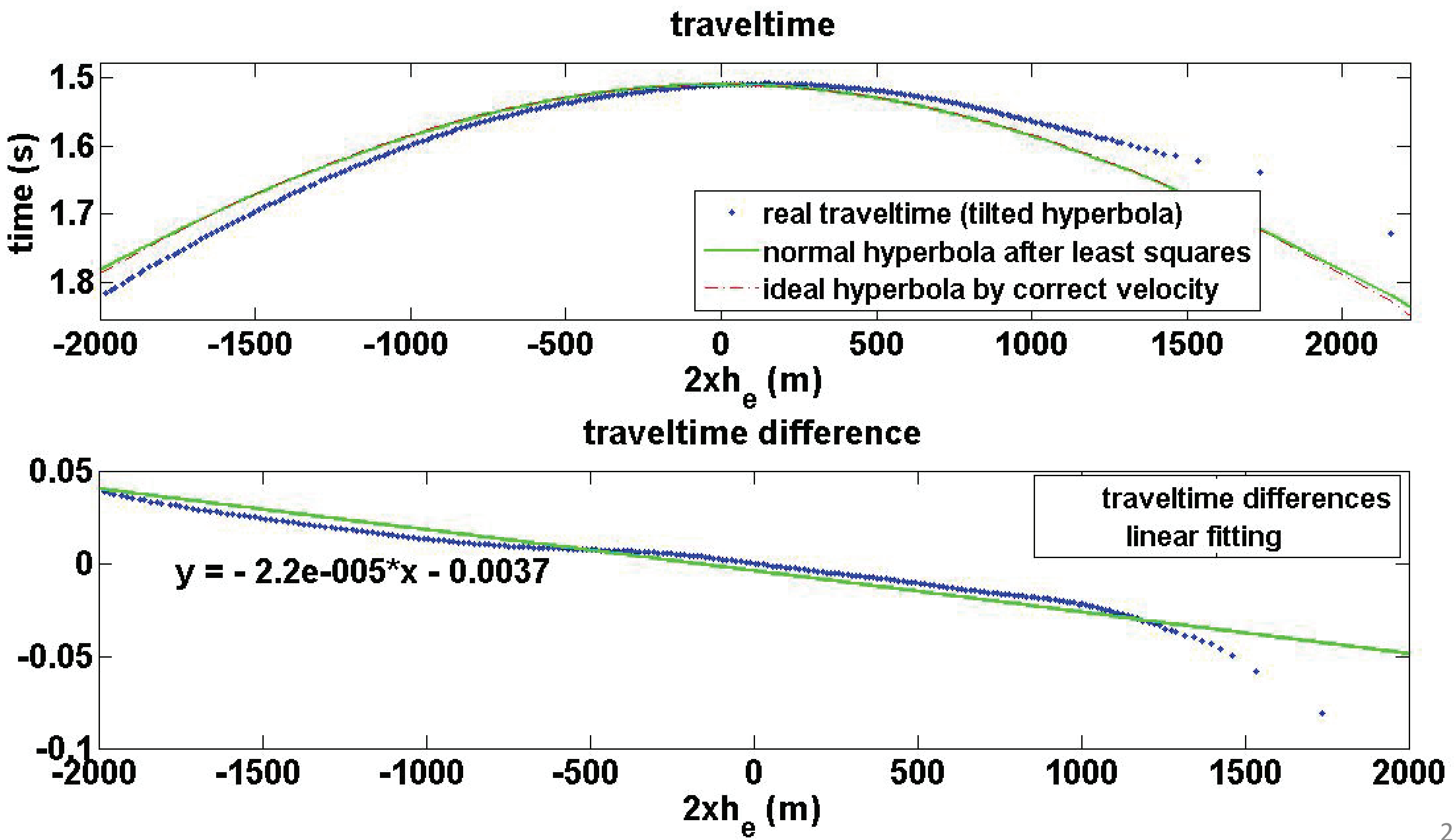
$$\begin{bmatrix} x_1^2 & x_1 y_1 & y_1^2 & x_1 & y_1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{1n}^2 & x_n y_n & y_n^2 & x_n & y_n & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \\ D \\ E \\ F \end{bmatrix} = \begin{bmatrix} r_i \\ \vdots \\ r_n \end{bmatrix}$$

Leary et al. (2004)

"Direct and specific least-square fitting of hyperbolæ and ellipses, **Journal of Electronic Imaging** 13(3), 492– 503"

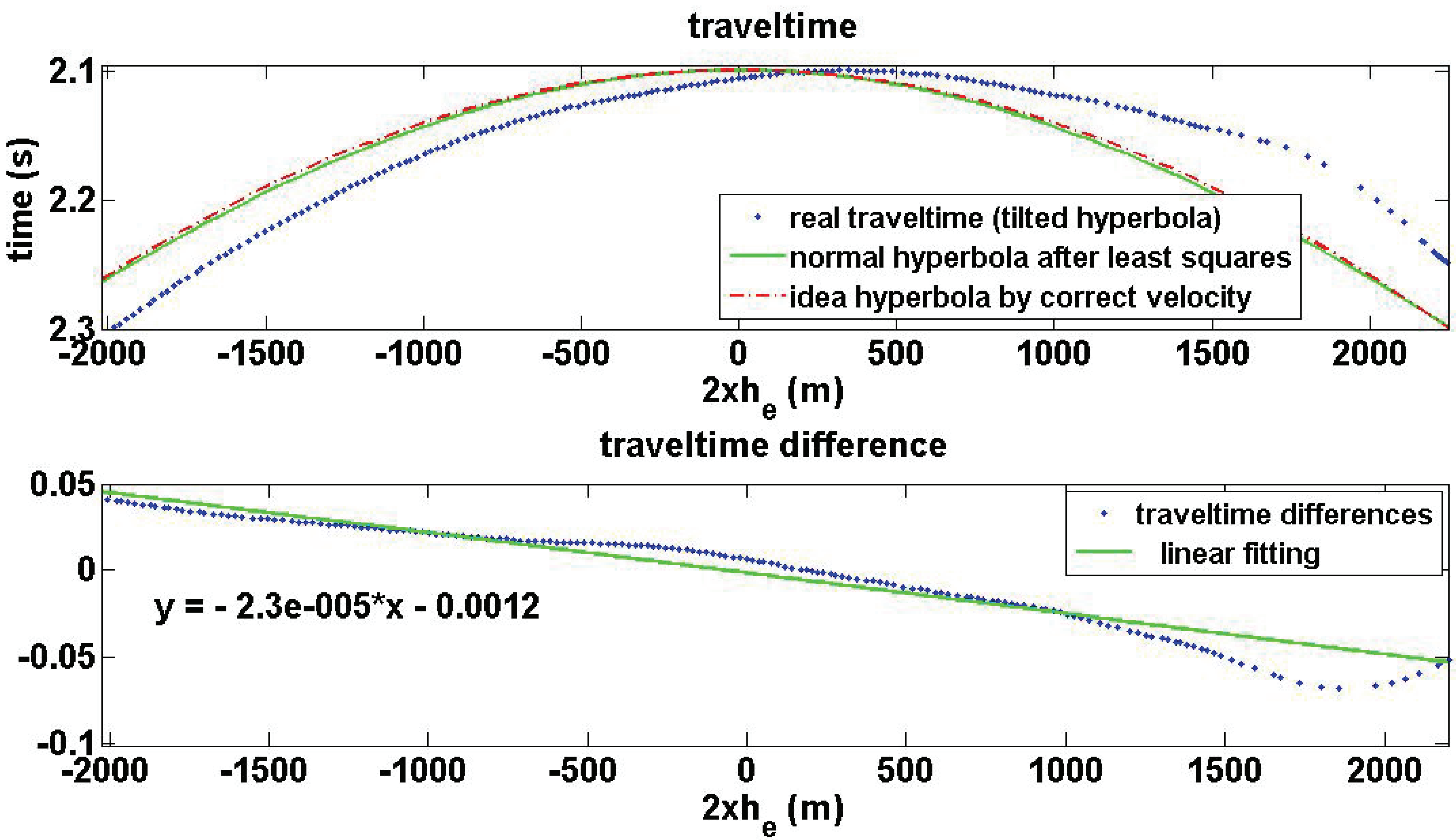
hyperbola least squares fitting

Scatterpoint A



Hyperbola least squares fitting

Scatterpoint B



Linear time shifted hyperbolic Radon transform

$$u(t_0,V)=\int_{h_e} D\left(t=\sqrt{t_0^2+\left(\frac{2h_e}{V}\right)^2},2h_e\right)dh_e$$

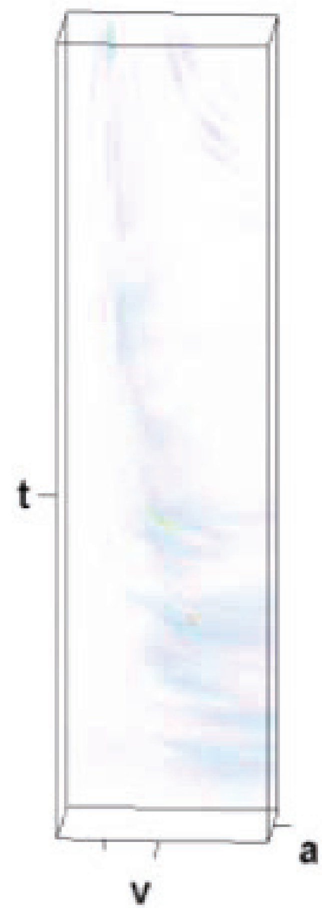
u =hyperbolic Radon domain

D= CSP signal in equivalent offset domain

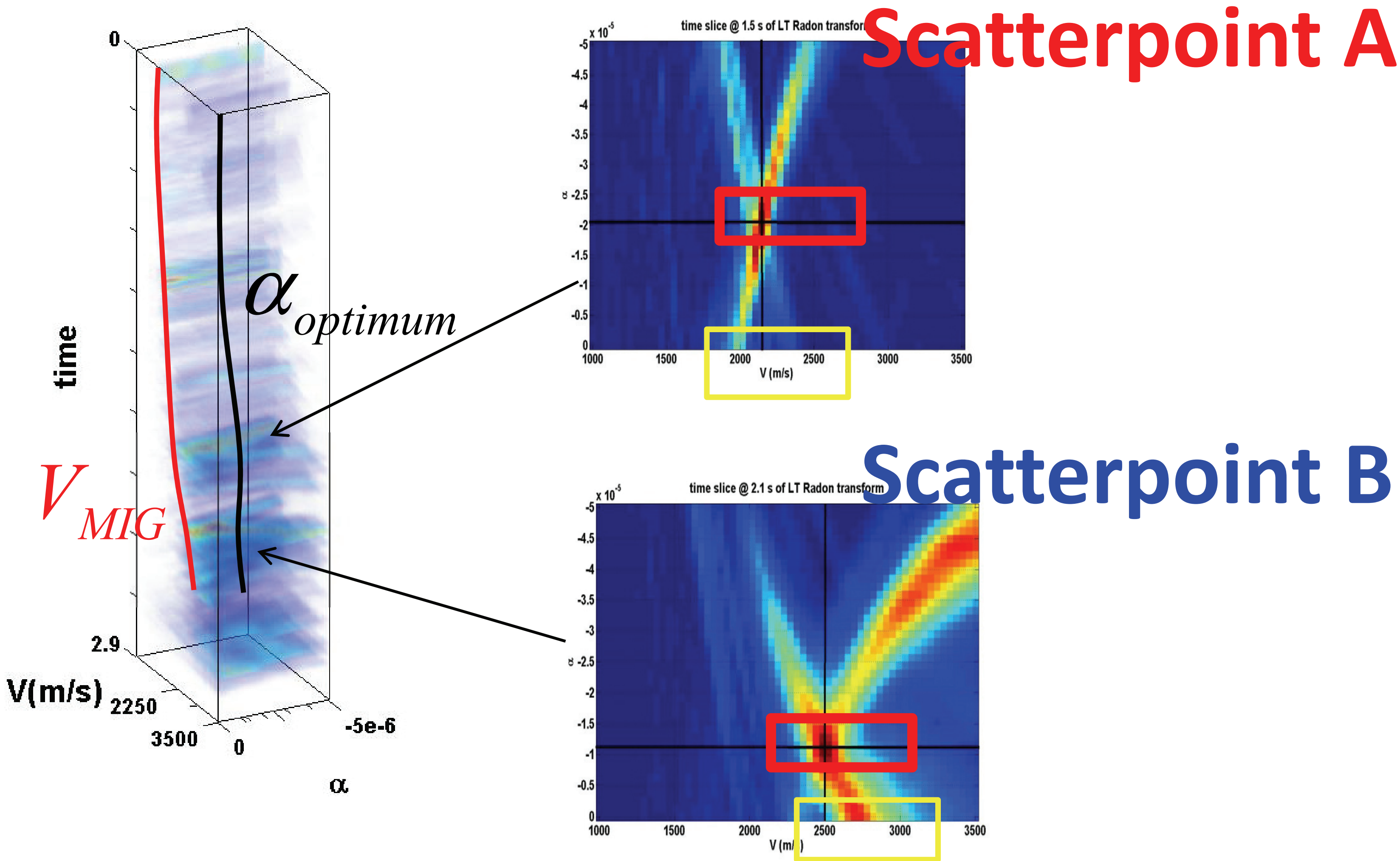
$$u_{LTS}(t_0,V,\alpha)=\int_{\alpha}\int_{h_e} D\left(t=\sqrt{t_0^2+\left(\frac{2h_e}{V}\right)^2}+h_e\alpha,2h_e\right)dh_e d\alpha$$

u_{LTS} =Linear Timed Shift hyperbolic Radon domain

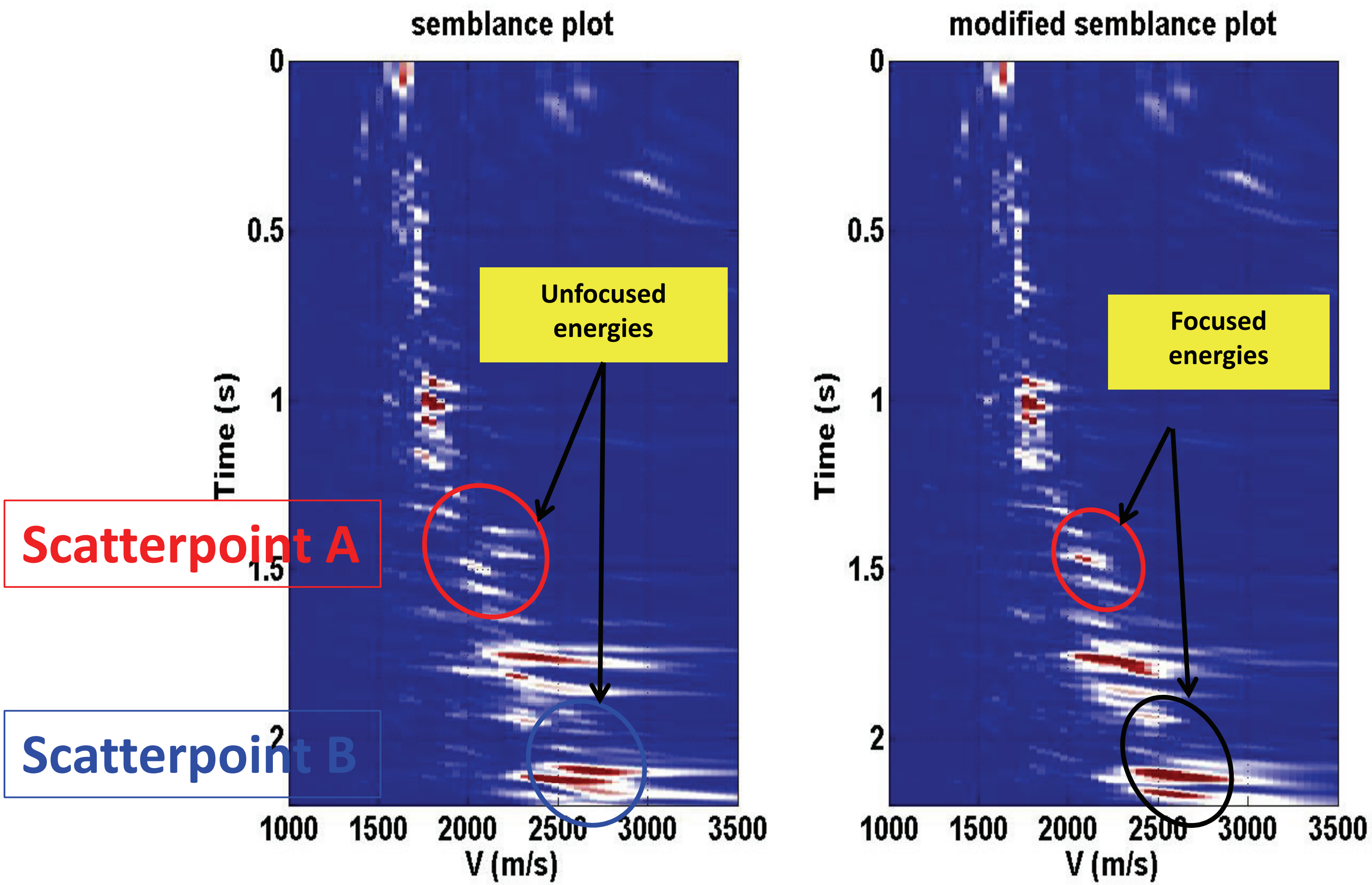
Semblance cube in transparent mode



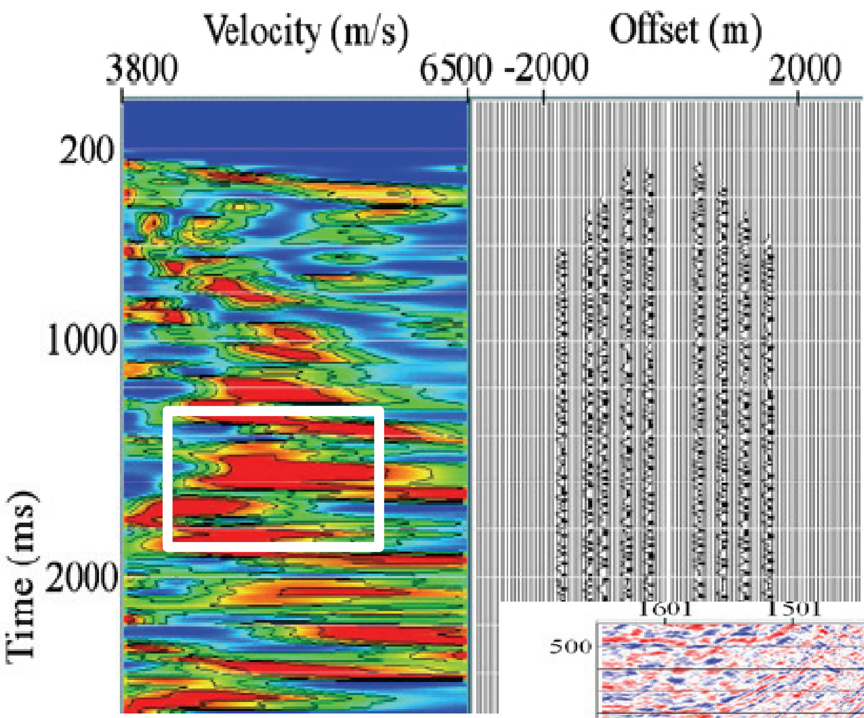
LTS semblance cube velocity picking

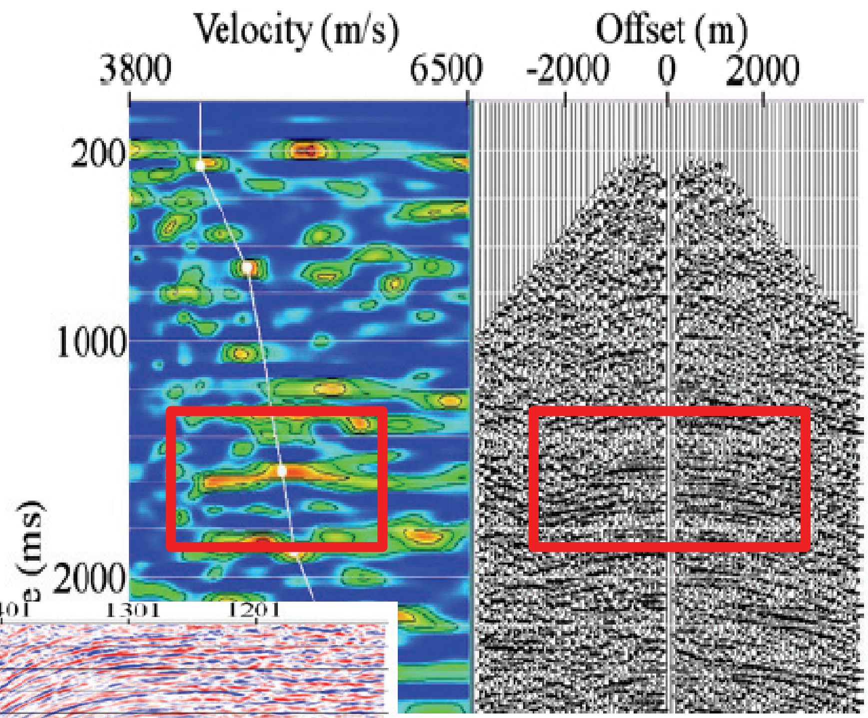


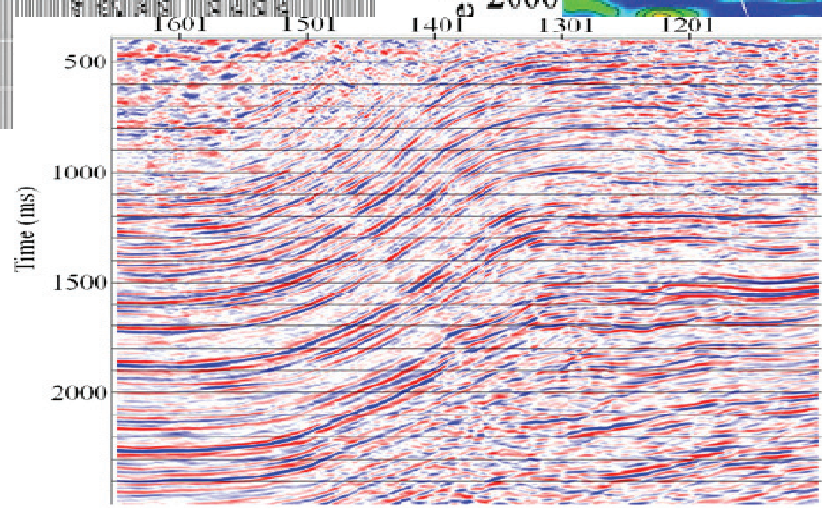
LTS semblance cube velocity picking



Field data example: MJ area in Sichuan province, western China







by permission from Zhang et al. (2006)

J. Geophys. Eng. 3 (2006) 283–289

Conclusions

- The effect of dipping interface on CSP data is tilted hyperbola. It reduces the resolution of the semblance plots.
- To enhance the velocity picking, the tilt effects can be removed by :
    - Hyperbola Least squares fitting approach
    - Hyperbolic linear time shifting Radon transform

Acknowledgments

- CREWES sponsors for financial suppurts
- Dr. Gary F. Margrave
- Dr. Pat Daley
- Dr. Hugh Geiger
- Dr. Maria K. Cameron
- Faranak Mahmoudian

THANK YOU