Diffractions: Do we exploit the imaging potential?

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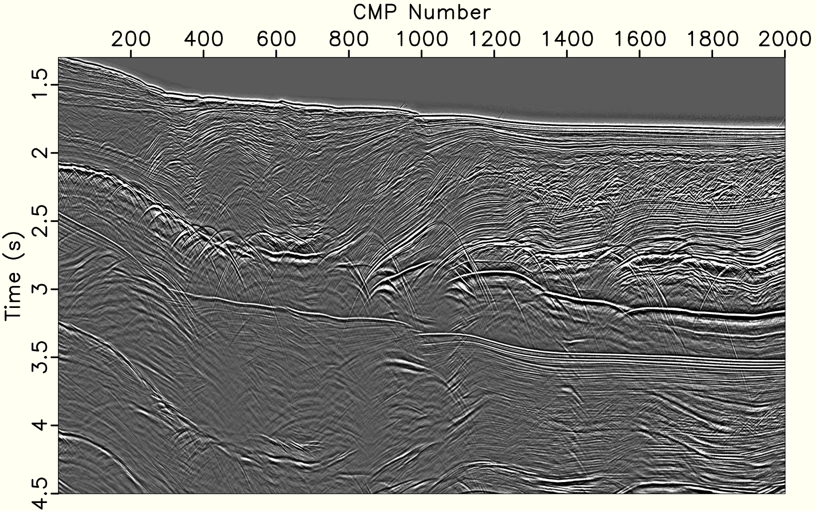
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Abundance of Diffractions



Levantine Basin, Mediterranean Sea

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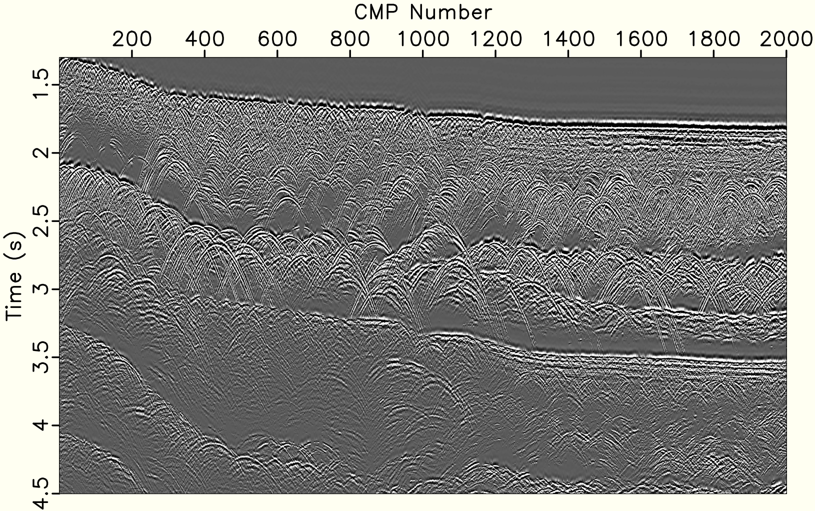

After diffraction separation

Motivation

- Abundance of diffractions

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- Illumination

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- Small scale features

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- FO tomography from ZO data

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Tool: Multi-parameter Processing (CRS)
Application of wavefield attributes

Agenda

- Common Reflection Surface

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- Decomposition principle for diffractions

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- FO diffraction tomography with ZO data

Common Reflection Surface

Zero-offset CRS traveltime moveout (Müller, 1999):

$$t_{\mathrm{ZO}}(\Delta x_m, h) = t_0^{\mathrm{ZO}} + \frac{2\sin\alpha_0}{v_0}\Delta x_m + \frac{\cos^2\alpha_0}{v_0}\left(\frac{\Delta x_m^2}{R_{\mathrm{N}}} + \frac{h^2}{R_{\mathrm{NIP}}}\right)$$

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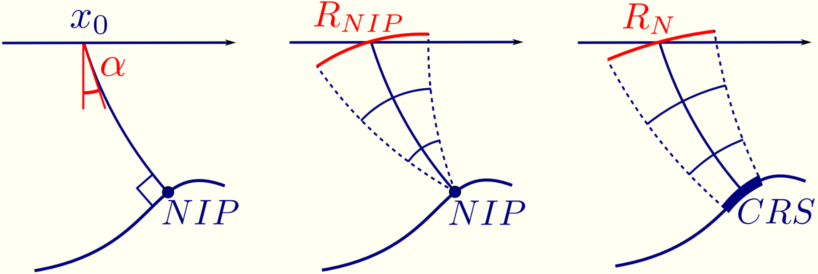

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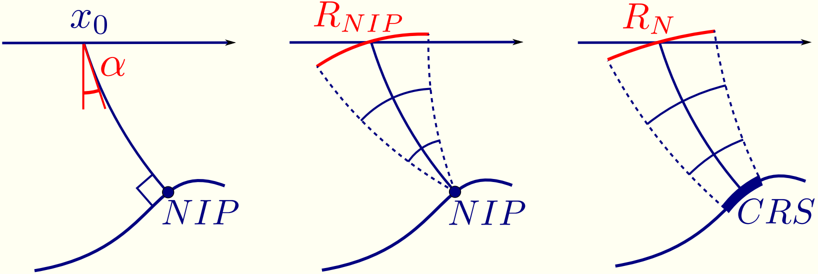

$\Delta x_m = 0 \Rightarrow$ CMP operator

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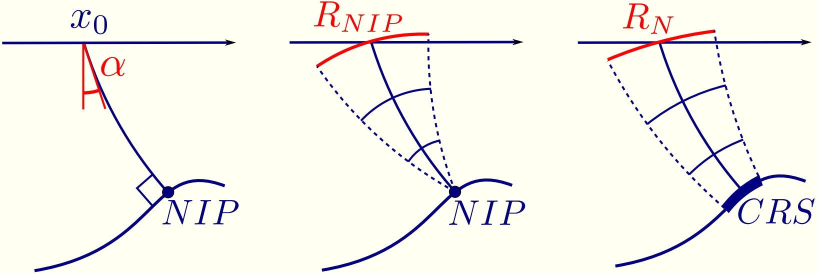
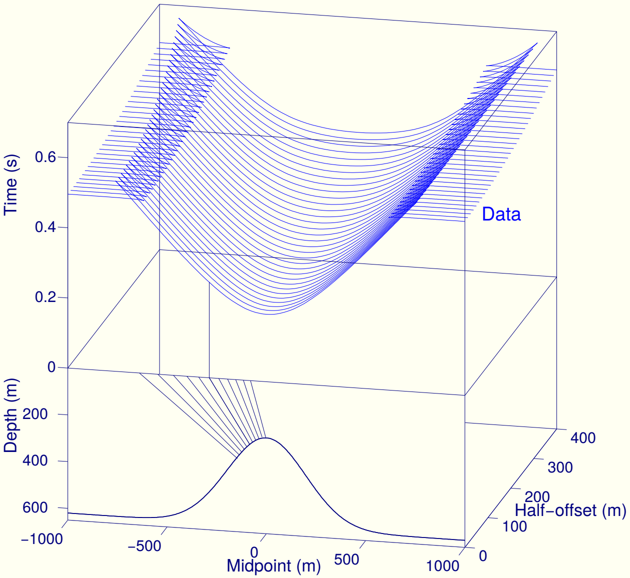


$\Delta x_m = 0 \Rightarrow$ CMP operator

For diffractions $R_N = R_{NIP}$

Common Reflection Surface



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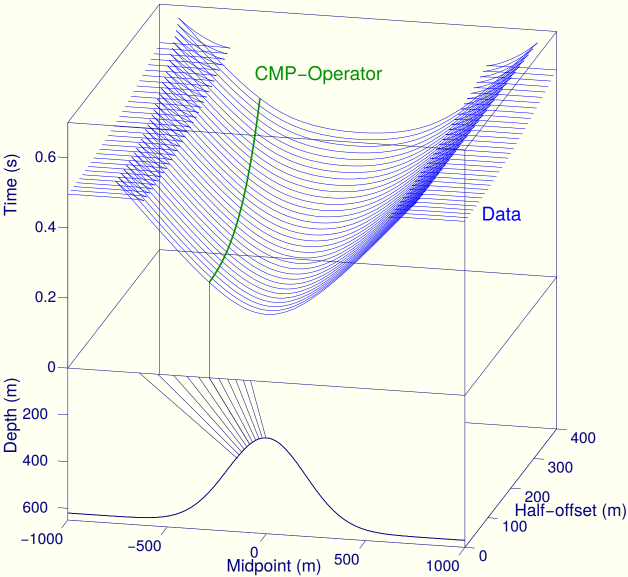

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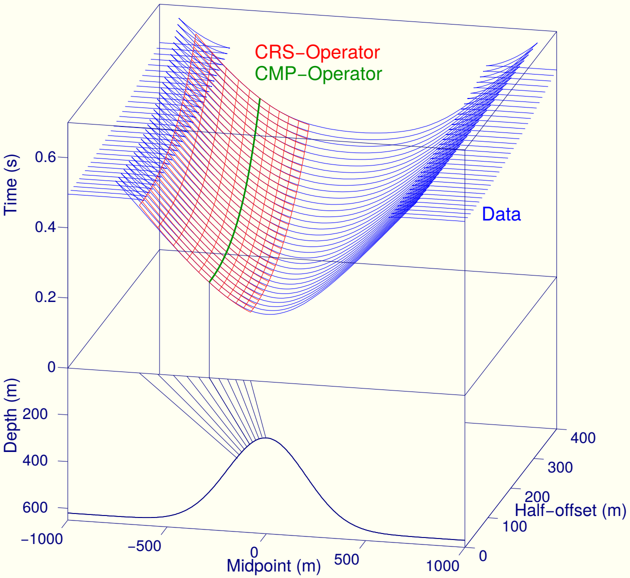
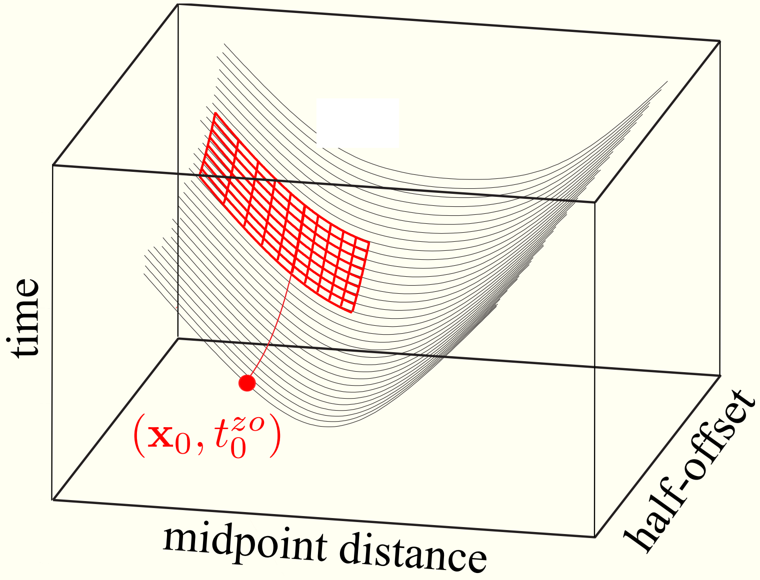
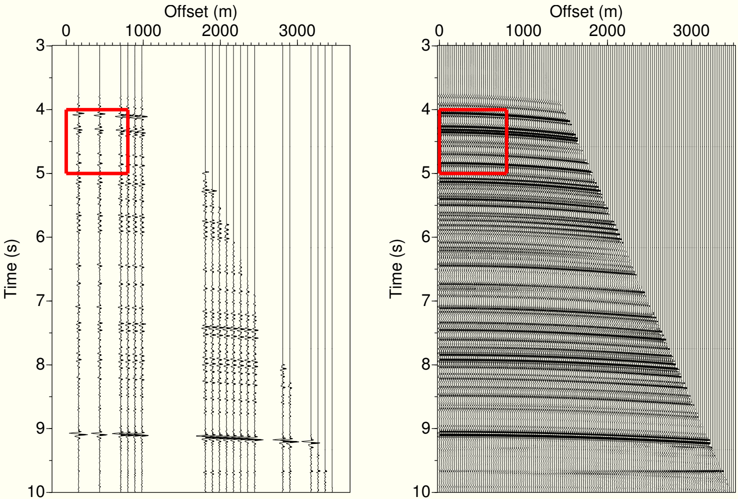


Offset Extrapolation – Partial Stacks



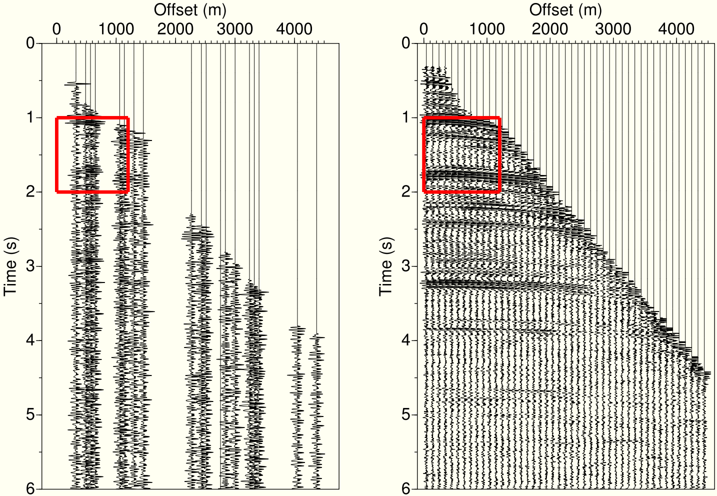
Application Partial Stacks

Pre-stack data enhancement and regularization (SIGSBEE):

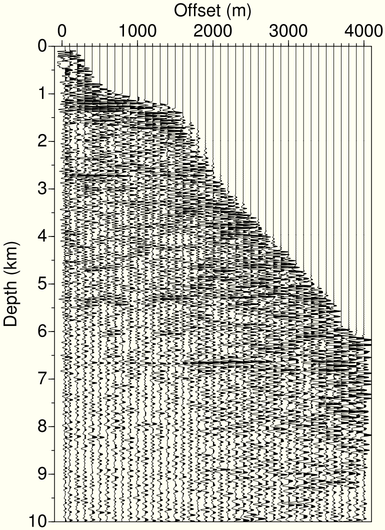


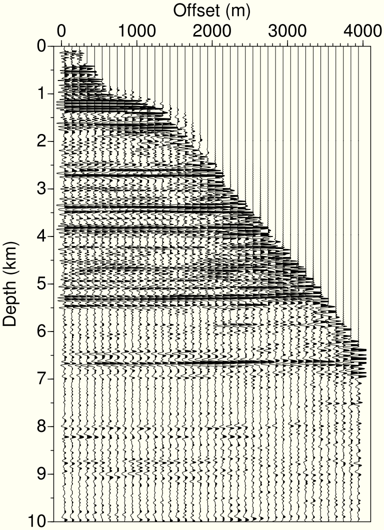
Application Partial Stacks

Pre-stack data enhancement and regularization (low fold field data):



QC Velocity Model





Reflection Traveltime Moveout

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Finite-offset CRS (Zhang et al., 2001):

$$\begin{aligned} t_{\mathrm{FO}}(\Delta x_s, \Delta x_g) = t_0^{\mathrm{FO}} &+ \frac{\sin\alpha_s}{v_s}\Delta x_s + \frac{1}{2}\frac{\cos^2\alpha_s}{v_s R_s}\Delta x_s^2 \\ &+ \frac{\sin\alpha_g}{v_g}\Delta x_g + \frac{1}{2}\frac{\cos^2\alpha_g}{v_g R_g}\Delta x_g^2 \\ &+ B^{-1}\Delta x_s \Delta x_g \end{aligned}$$

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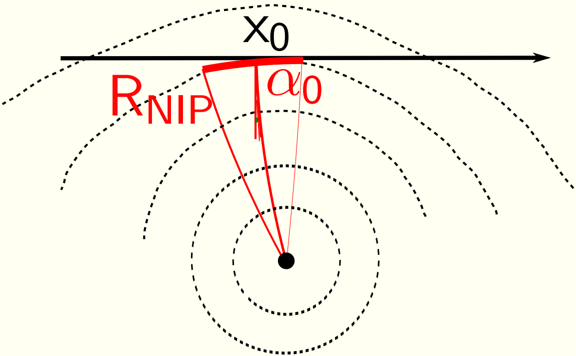
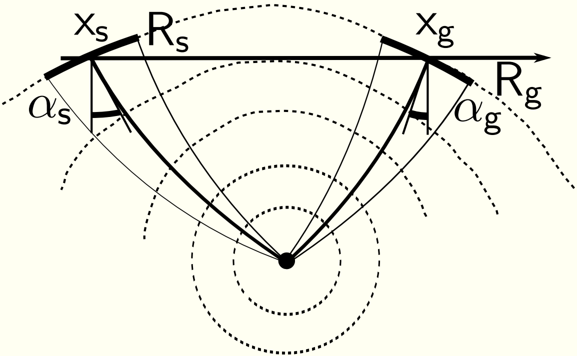
Zero-Offset Diffraction Response



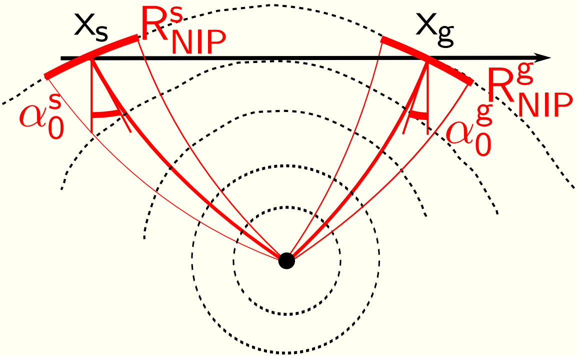
$$t_{ZO}(\Delta x_m) = t_0^{ZO} + \frac{2\sin\alpha_0}{v_0}\Delta x_m + \frac{\cos^2\alpha_0}{v_0 R_{NIP}}\Delta x_m^2$$

Finite-Offset Diffraction Response



$$t_{FO}(\Delta x_s, \Delta x_g) = t_0^{FO} + \frac{\sin\alpha_s}{v_s}\Delta x_s + \frac{1}{2}\frac{\cos^2\alpha_s}{v_s R_s}\Delta x_s^2 + \frac{\sin\alpha_g}{v_g}\Delta x_g + \frac{1}{2}\frac{\cos^2\alpha_g}{v_g R_g}\Delta x_g^2$$

Decomposition Principle



$$t_{FO}(x_s, x_g, t_0^{FO}, \alpha_s, \alpha_g, R_s, R_g) = \frac{t_{ZO}(x_s, t_0^{ZO,s}, \alpha_0^s, R^s_{NIP})}{2} + \frac{t_{ZO}(x_g, t_0^{ZO,g}, \alpha_0^g, R^g_{NIP})}{2}$$

FO Prediction for Diffractions

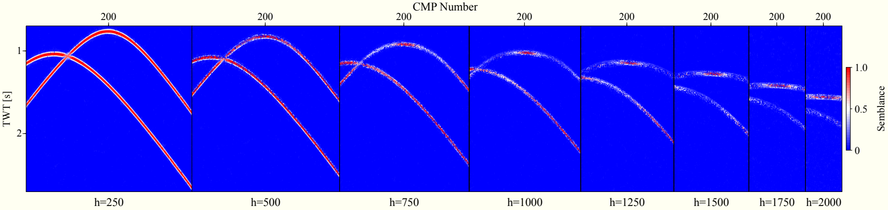
Decoupling of diffraction raypaths allows to obtain FO diffraction attributes directly from ZO results by

$$\alpha_s = \alpha_0^s$$
$$\alpha_g = \alpha_0^g$$
$$R_s = R_{\mathrm{NIP}}^s$$
$$R_g = R_{\mathrm{NIP}}^g$$
$$t_0^{\mathrm{FO}} = \left(t_0^{\mathrm{ZO},s} + t_0^{\mathrm{ZO},g} \right) /2$$

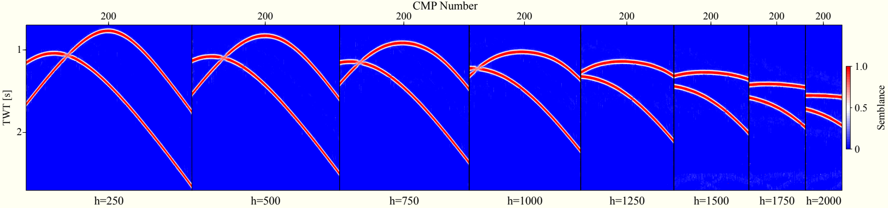
These relations are exact for diffractions in arbitrary media provided reciprocity

Simple Data Example

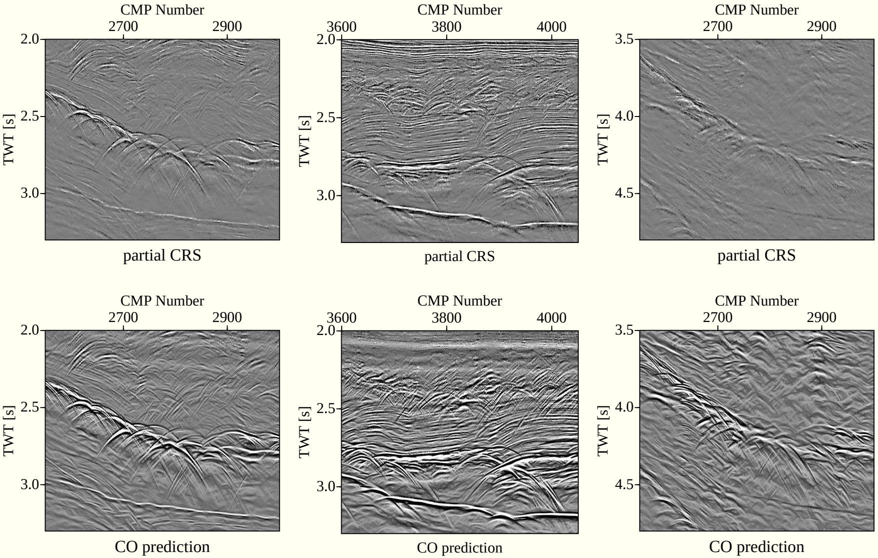
Partial CRS (offsets 500 to 4000 m):



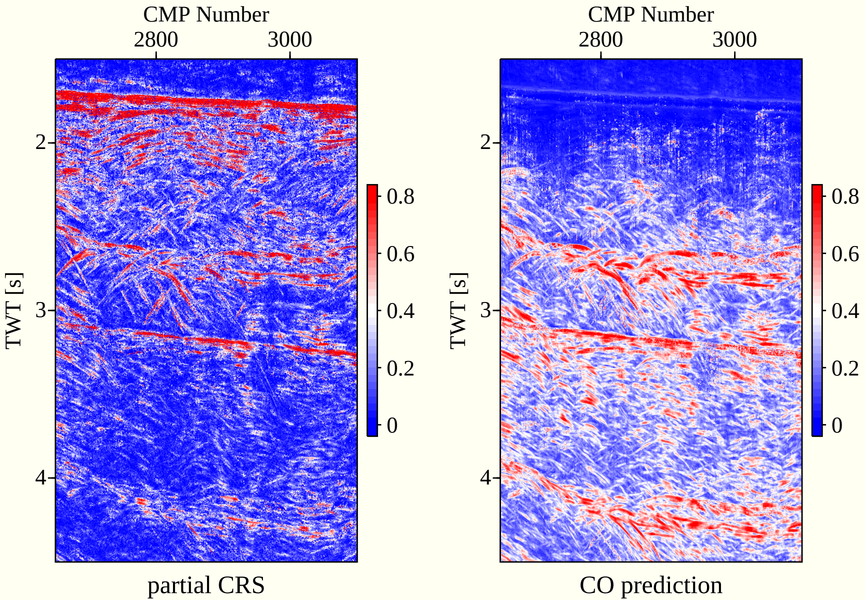
FO prediction (offsets 500 to 4000 m):



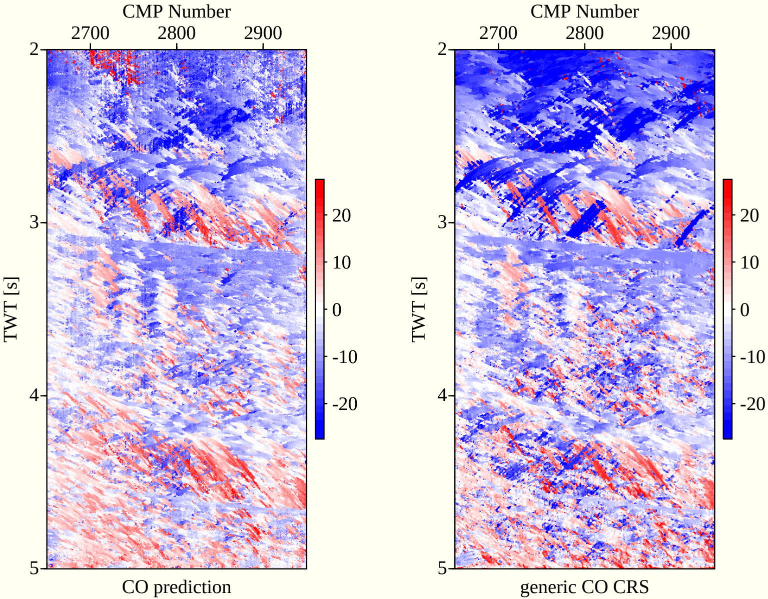
Field Data: Stack (FO 1000 m)



Field Data: Semblance (FO 1000 m)



Field data: α_s [°] (FO 1000 m)



Implications

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- Accurate ZO-based prediction of FO diffraction operators

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- High quality FO diffraction attributes

Pitfals

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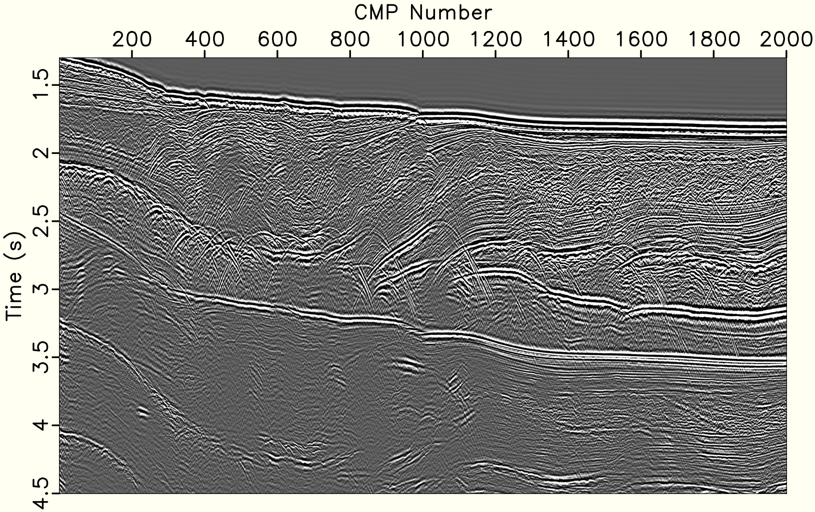
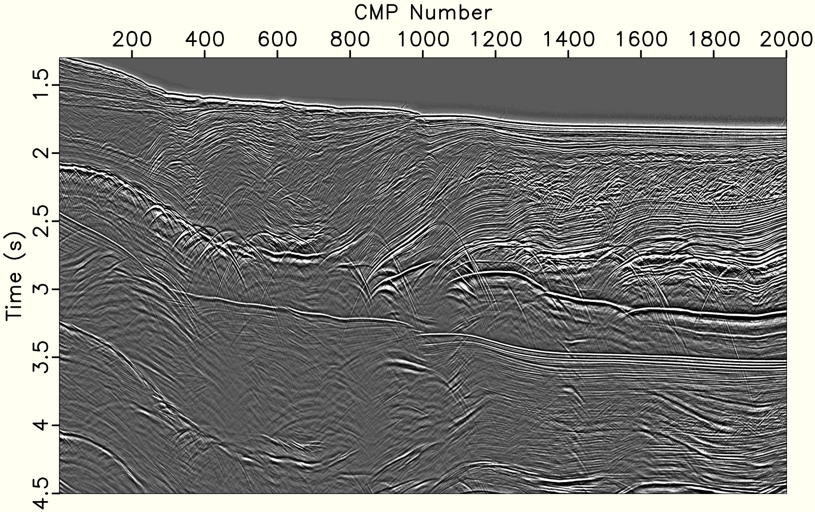
Local Optimization



Global Optimization



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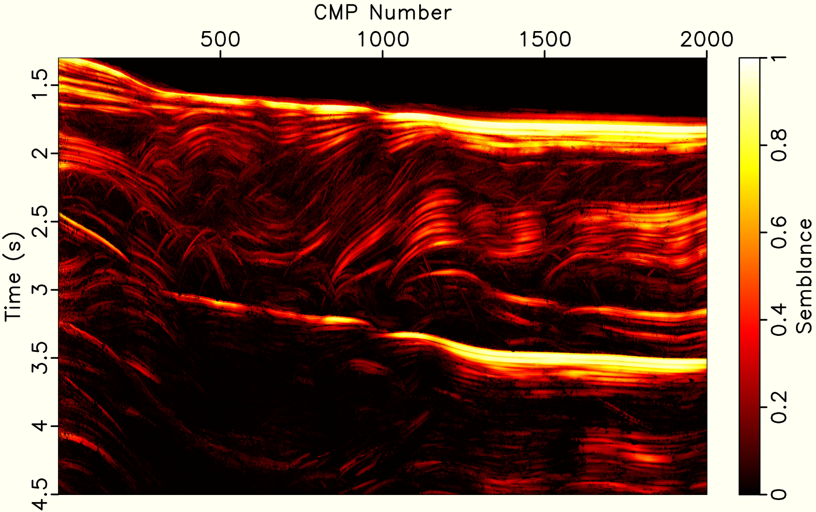

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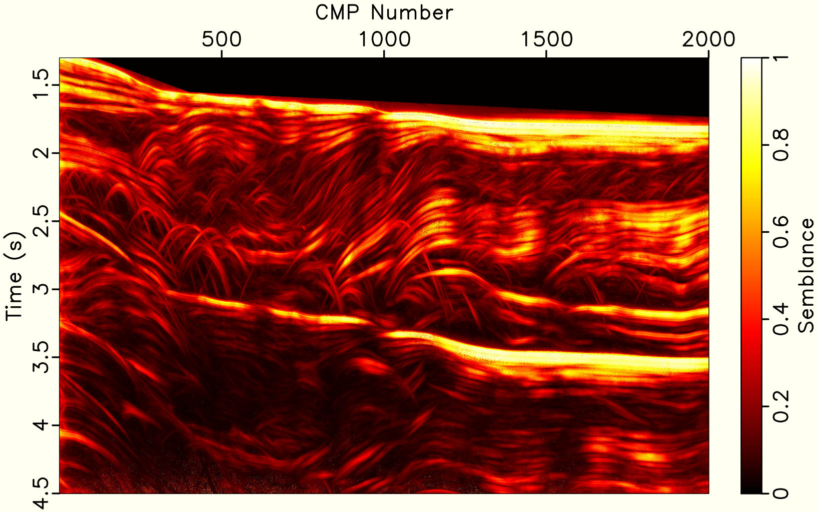
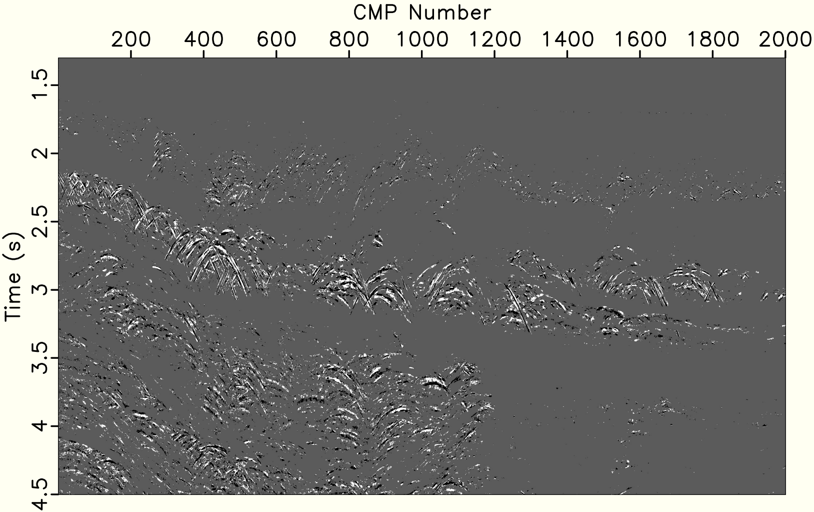


Separation Without Conflicting Dips



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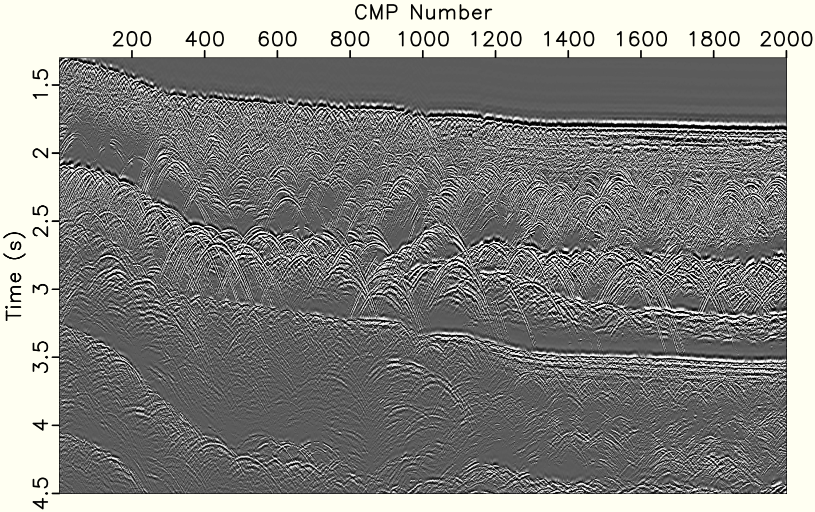
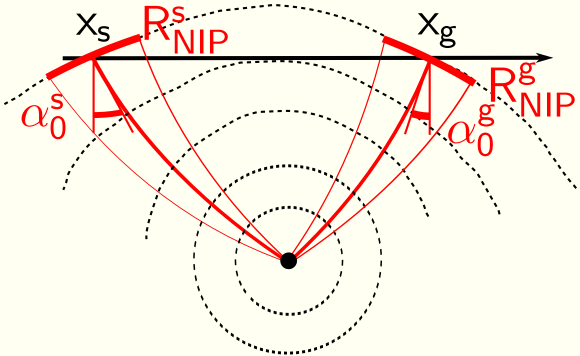


FO Diffraction Tomography



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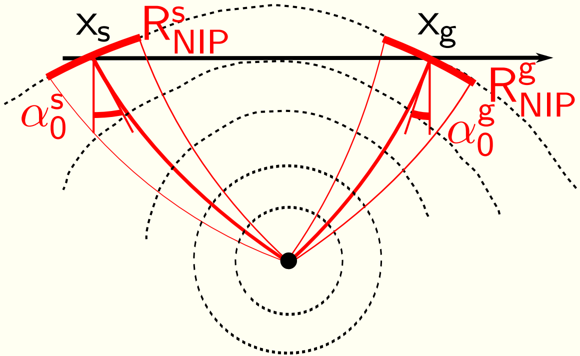

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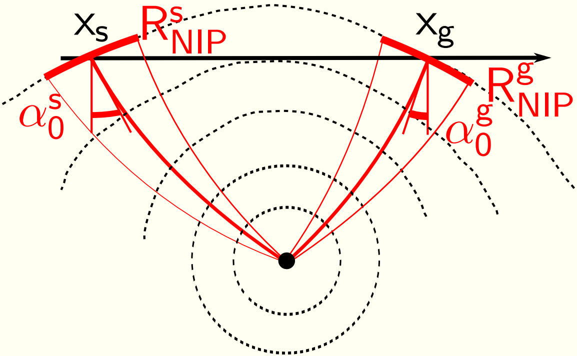

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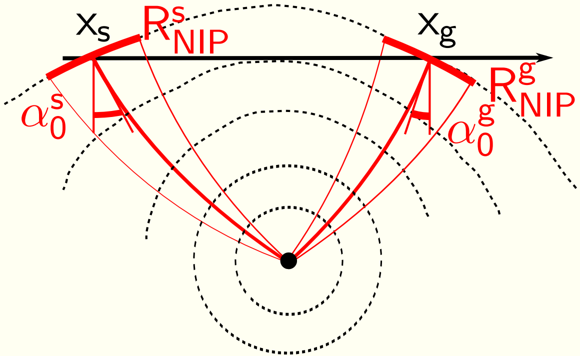

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- Entirely based on NIP rays
- Uses NIP-wave tomography

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- Gateway to measured Green's functions

Conclusions

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Acknowledgments

- Applied Seismics Group, University of Hamburg, for enlightening discussions
- TGS-NOPEC for field data
- NORSAR for ray software
- SMAART JV for SIGSBEE
- Sponsors of the WIT consortium for financial support