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Macro-model Independent Pre-stack Time Migration

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Overview

- Motivation
- Eigenwaves and wavefield attributes
- Pre-stack time migration vs. common-reflection-surface (CRS) stack
- Model-independent approximation of migration operator
- Application to 2-D deep-offshore data
- Conclusions

Motivation

Seismic Reflection Imaging

Final aim:	Image of subsurface in depth domain
Problem:	Sufficiently accurate velocity model required
Compromise:	Time migration, less sensitive to model errors

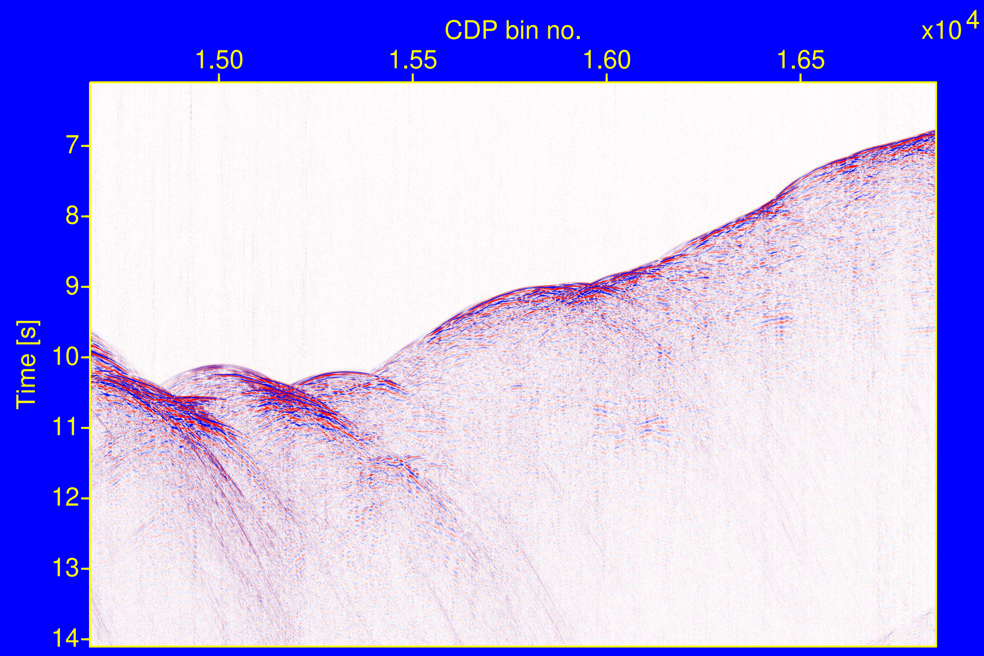
Imaging without velocity model

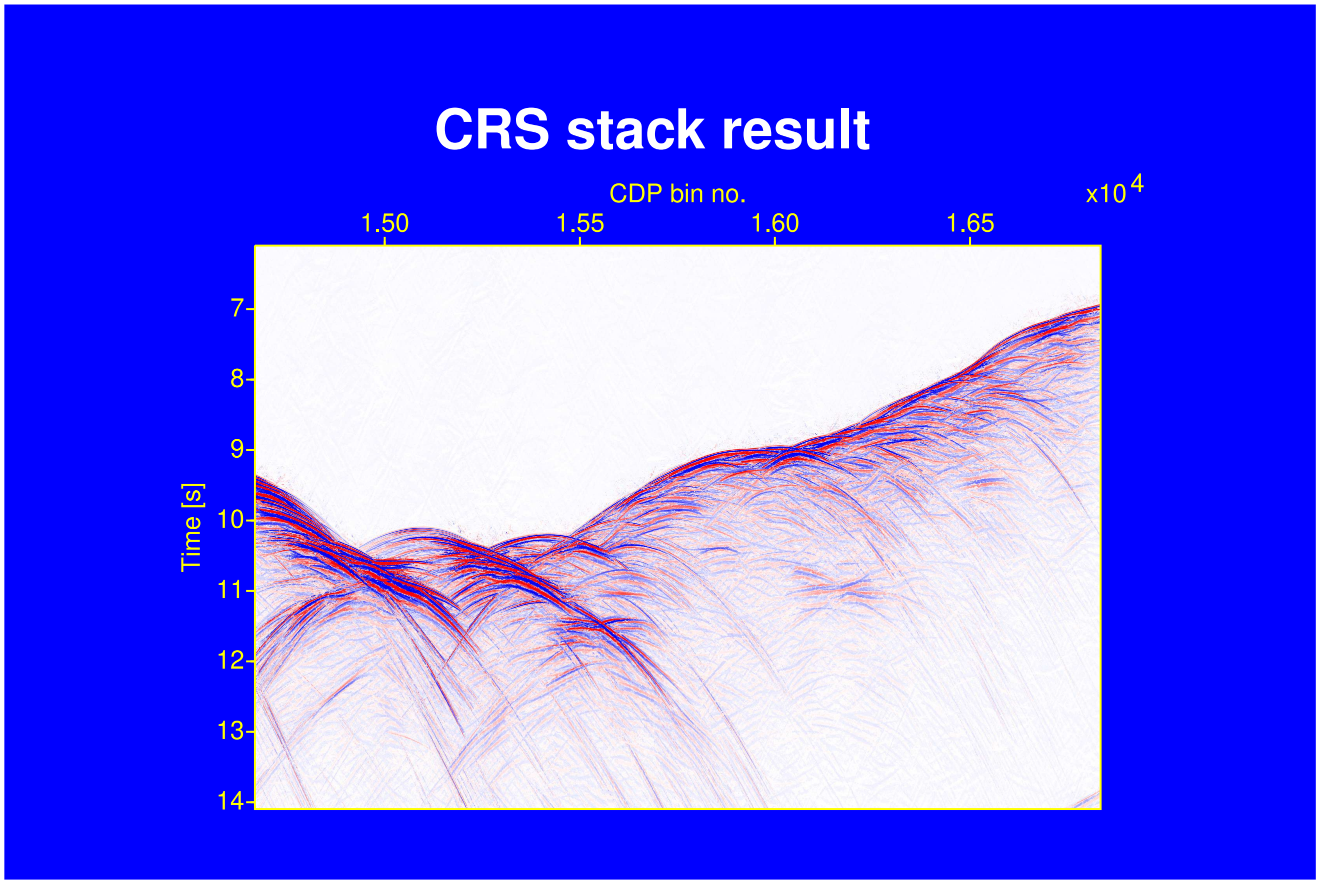
Common-Reflection-Surface (CRS) stack

- only near-surface velocity required
- simulated zero-offset section
- three kinematic wavefield attributes

This is sufficient to approximate
a pre-stack time migration.

Conventional stack result




CRS stack result
CDP bin no.
x10^4
1.50
1.55
1.60
1.65
Time [s]
7
8
9
10
11
12
13
14

Eigenwaves and wavefield attributes

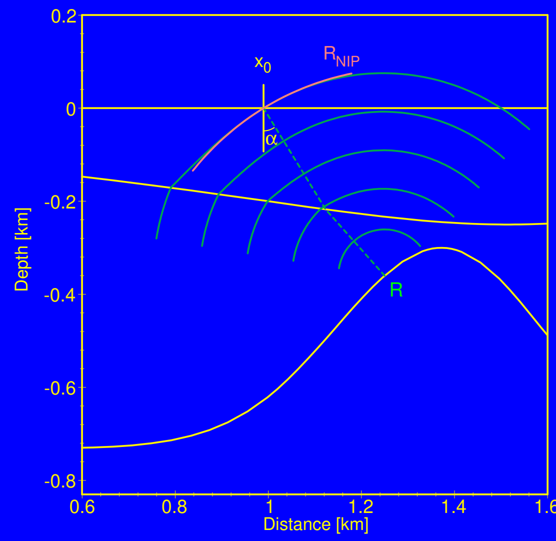
Two hypothetical experiments:

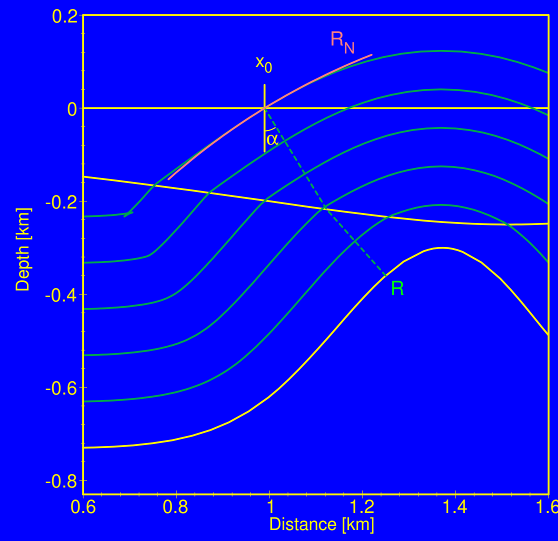
- Exploding reflector experiment
- Point source experiment

Arbitrarily curved interfaces:

- Superposition of both eigenwaves
- Three kinematic wavefield attributes

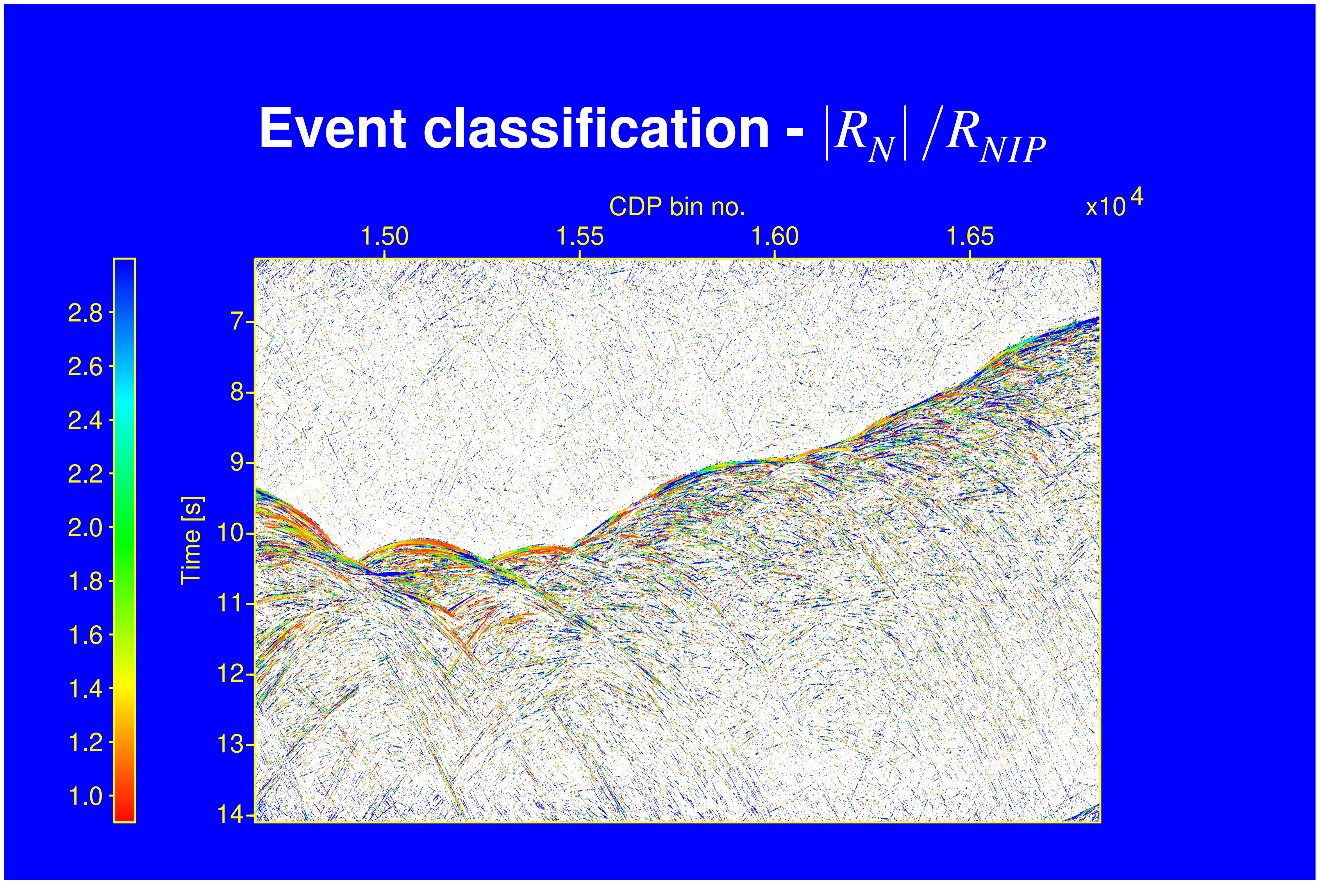
Hypothetical eigenwave experiments





Special case: Diffractors

- Both eigenwave experiments coincide
- Identical wavefronts, i. e. $R_N = R_{NIP}$
- CRS operator approximates migration operator



Event classification - $|R_N| / R_{NIP}$
CDP bin no.
x10^4
1.50
1.55
1.60
1.65
Time [s]
7
8
9
10
11
12
13
14
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0

Pre-stack time migration

Stacking operator:	Model-derived response of diffraction point
Image location:	Apex of stacking operator, corresponding ray normal to surface
Output:	Time-migrated section

Common-reflection-surface stack

Stacking operator:	Data-derived response of curved reflector segment
Image location:	ZO sample to be simulated, corresponding ray normal to reflector
Output:	Simulated ZO section

Time migration vs. CRS stack

Common aim of both methods:	stack coherent energy along actual reflection event
Basic difference:	image location
New approach:	use wavefield attributes to approximate image location of time migration

Approximation of image location

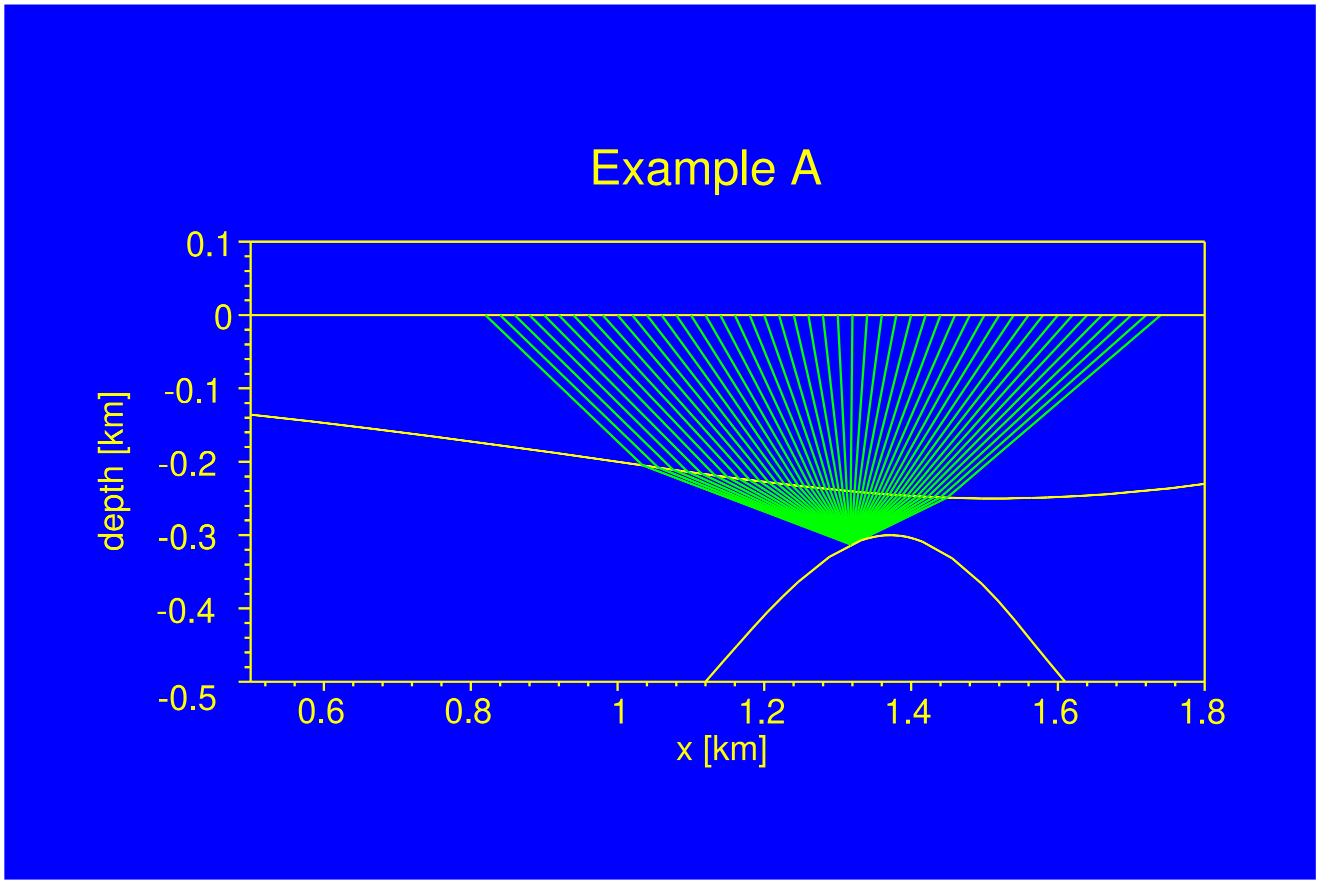
CRS operator

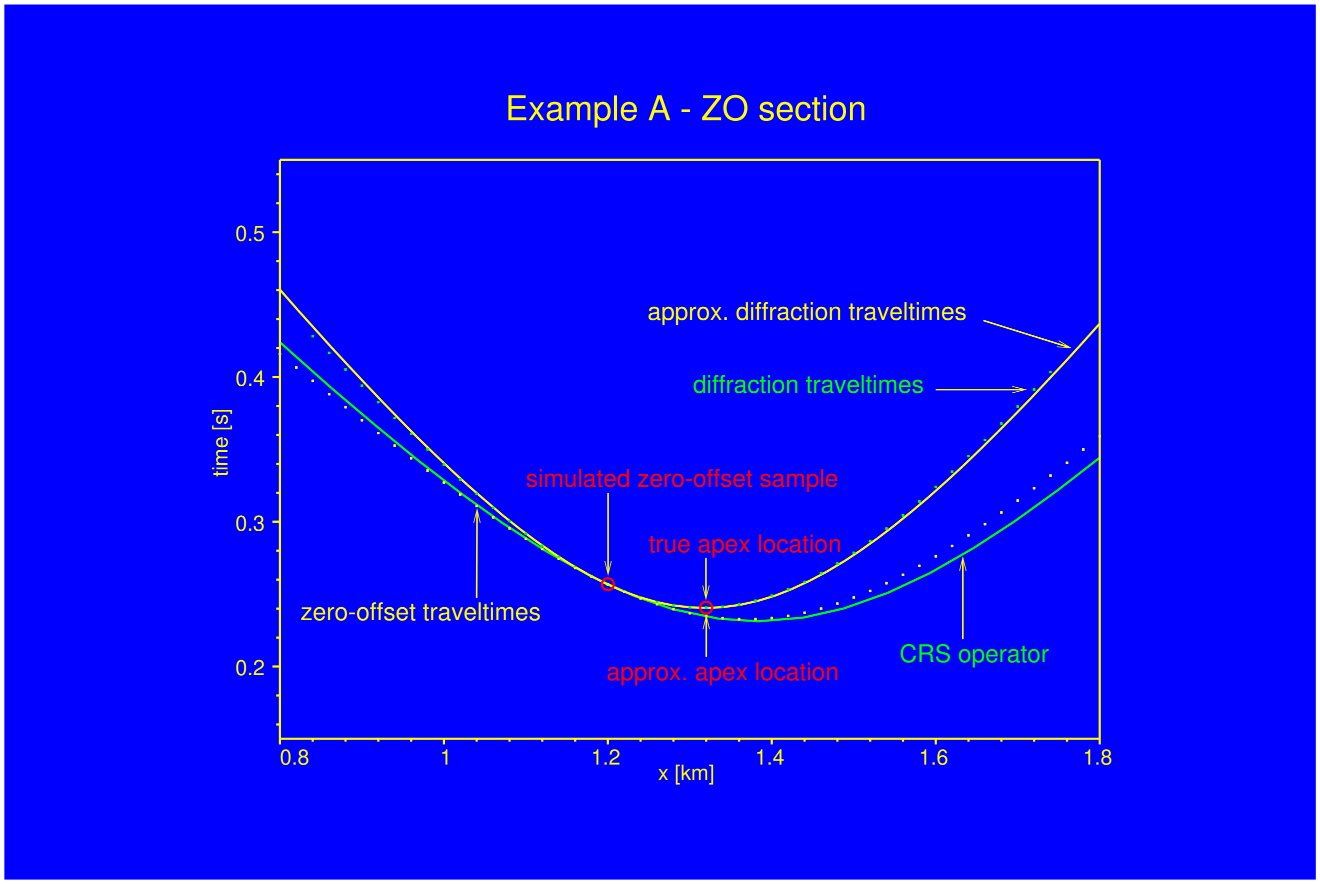
$$t^2(\Delta x, h) = \left(t_0 + \frac{2\sin\alpha}{v_0}\Delta x\right)^2 + \frac{2t_0\cos^2\alpha}{v_0}\left(\frac{\Delta x^2}{R_N} + \frac{h^2}{R_{NIP}}\right)$$

Corresponding diffraction operator: $R_N = R_{NIP}$

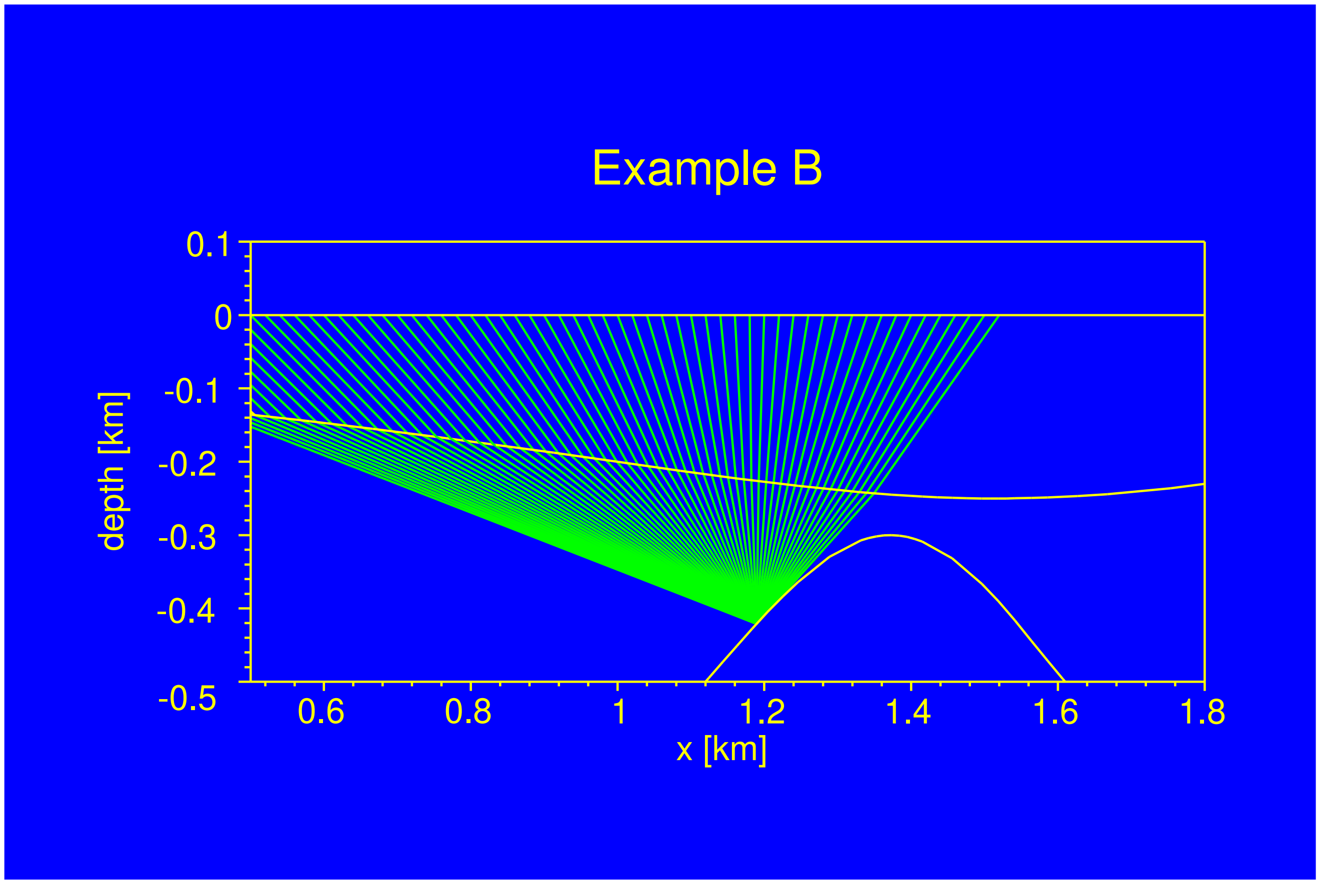
$$t^2(\Delta x, h) = \left(t_0 + \frac{2\sin\alpha}{v_0}\Delta x\right)^2 + \frac{2t_0\cos^2\alpha}{v_0 R_{NIP}}\left(\Delta x^2 + h^2\right)$$

Image location: apex of diffraction operator

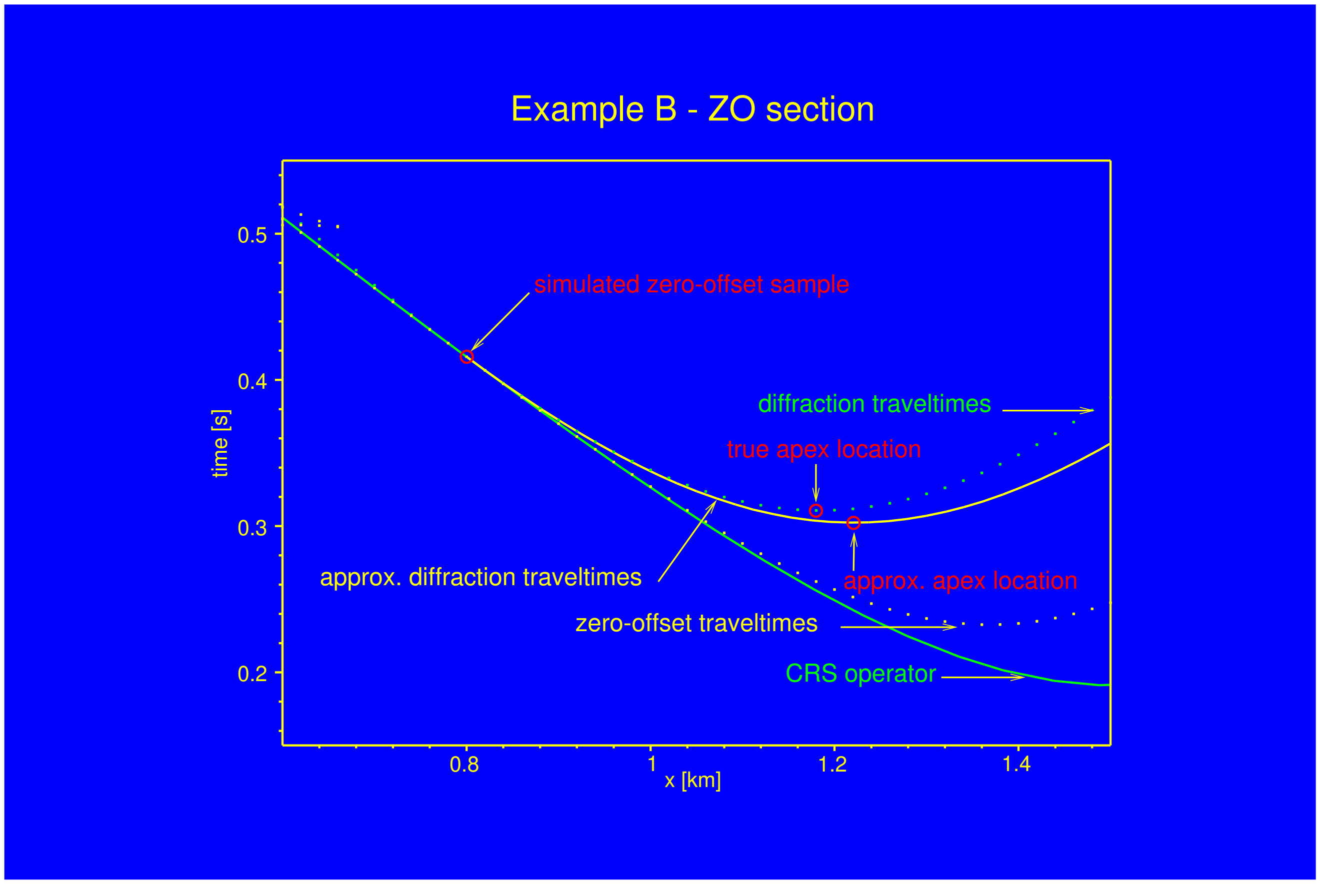

Example A
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
depth [km]
0.6
0.8
1
1.2
1.4
1.6
1.8
x [km]



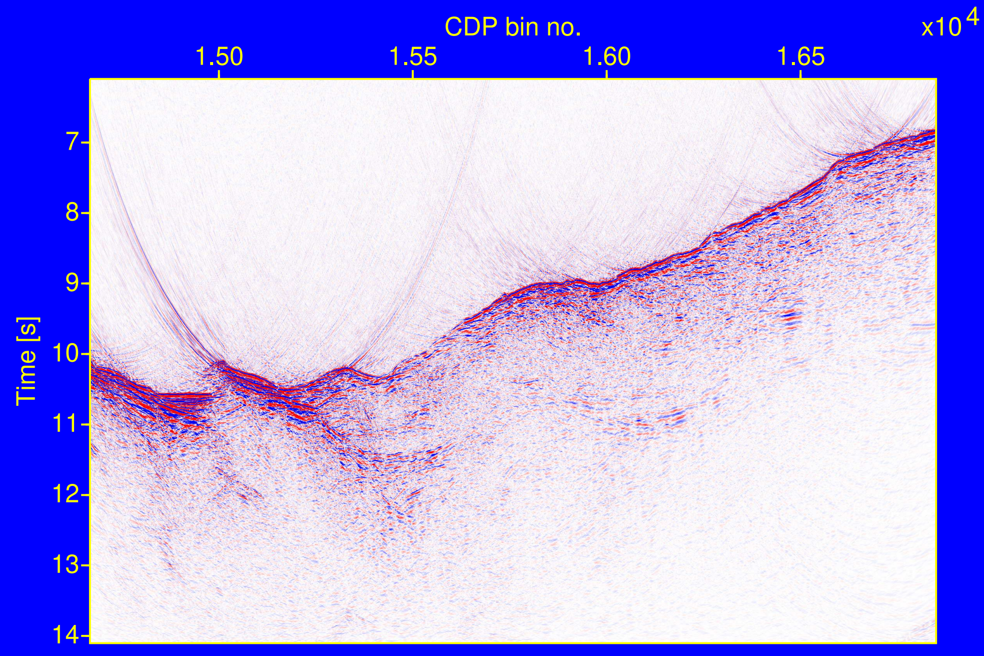
Example A - ZO section
approx. diffraction traveltimes
diffraction traveltimes
simulated zero-offset sample
true apex location
zero-offset traveltimes
approx. apex location
CRS operator
time [s]
0.5
0.4
0.3
0.2
0.8
1
1.2
1.4
1.6
1.8
x [km]



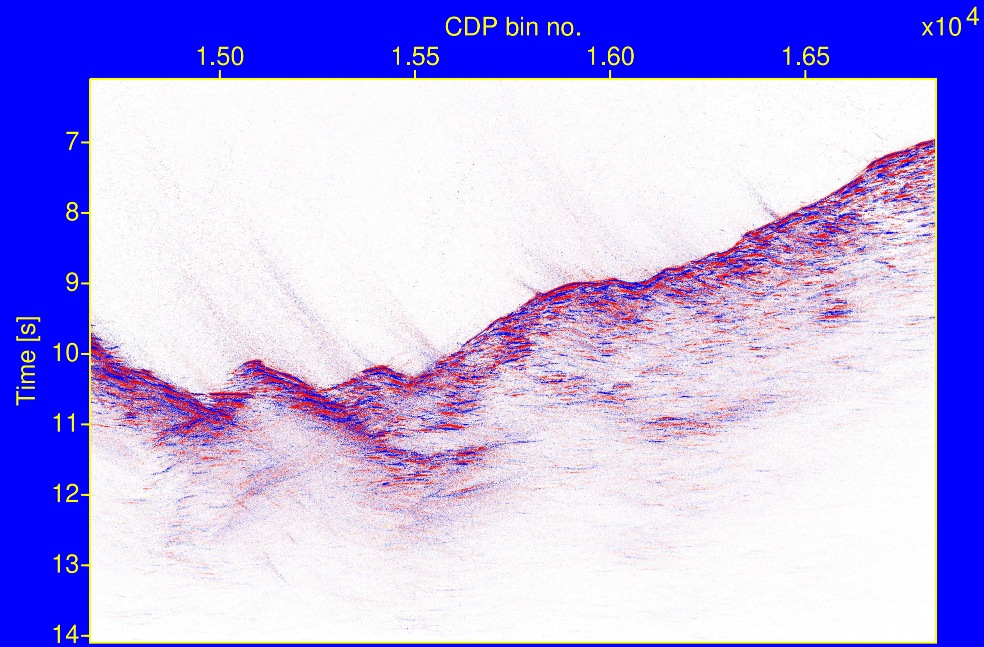
Example B
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
depth [km]
0.6
0.8
1
1.2
1.4
1.6
1.8
x [km]


Example B - ZO section
simulated zero-offset sample
diffraction traveltimes
true apex location
approx. diffraction traveltimes
approx. apex location
zero-offset traveltimes
CRS operator
time [s]
x [km]
0.5
0.4
0.3
0.2
0.8
1
1.2
1.4

Stolt migration of conventional stack



CRS based pre-stack time migration



Conclusions

CRS based pre-stack time migration

- no interval velocity model required
- accounts for conflicting dips
- inherently parsimonious
- high signal-to-noise ratio
- by-product of the CRS stack method
- very little additional effort

References

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Acknowledgements

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