Geophysical Institute
University of Karlsruhe

Common-Reflection-Surface Stack and Conflicting Dips

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SEG San Antonio 2001

Overview

- Basics of the CRS stack
- Pragmatic CRS search strategy
- Detection of conflicting dip situations
- Extended CRS search strategy
- NMO/DMO/stack vs. extended CRS stack
- Synthetic and real data examples
- Conclusions

Basics of the CRS stack

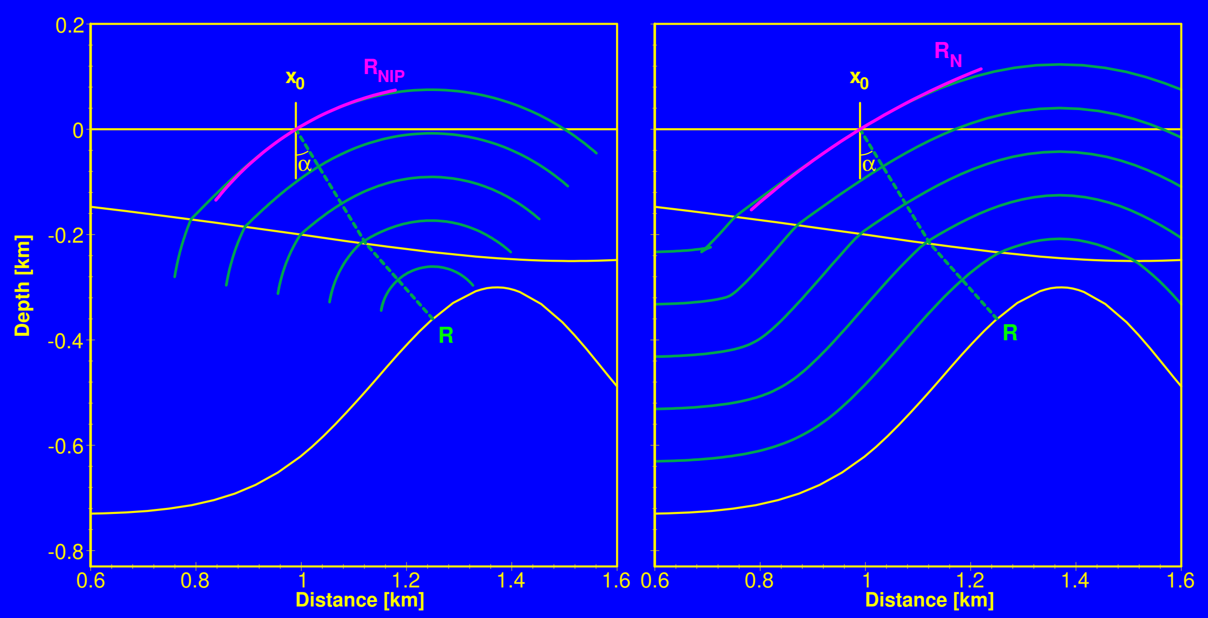
- data-driven simulation of 2-D zero-offset (ZO) sections
- analytic stacking operator with three parameters
- optimum stacking operator is determined by coherence analysis
- global optimization problem with three parameters

CRS stacking operator

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

Δx	midpoint displacement $x_m - x_0$
h	half offset
v_0	near-surface velocity
t_0	zero-offset traveltime
α	emergence angle of normal ray
R_{NIP}	radius of curvature of NIP wave
R_N	radius of curvature of normal wave

Hypothetical eigenwave experiments



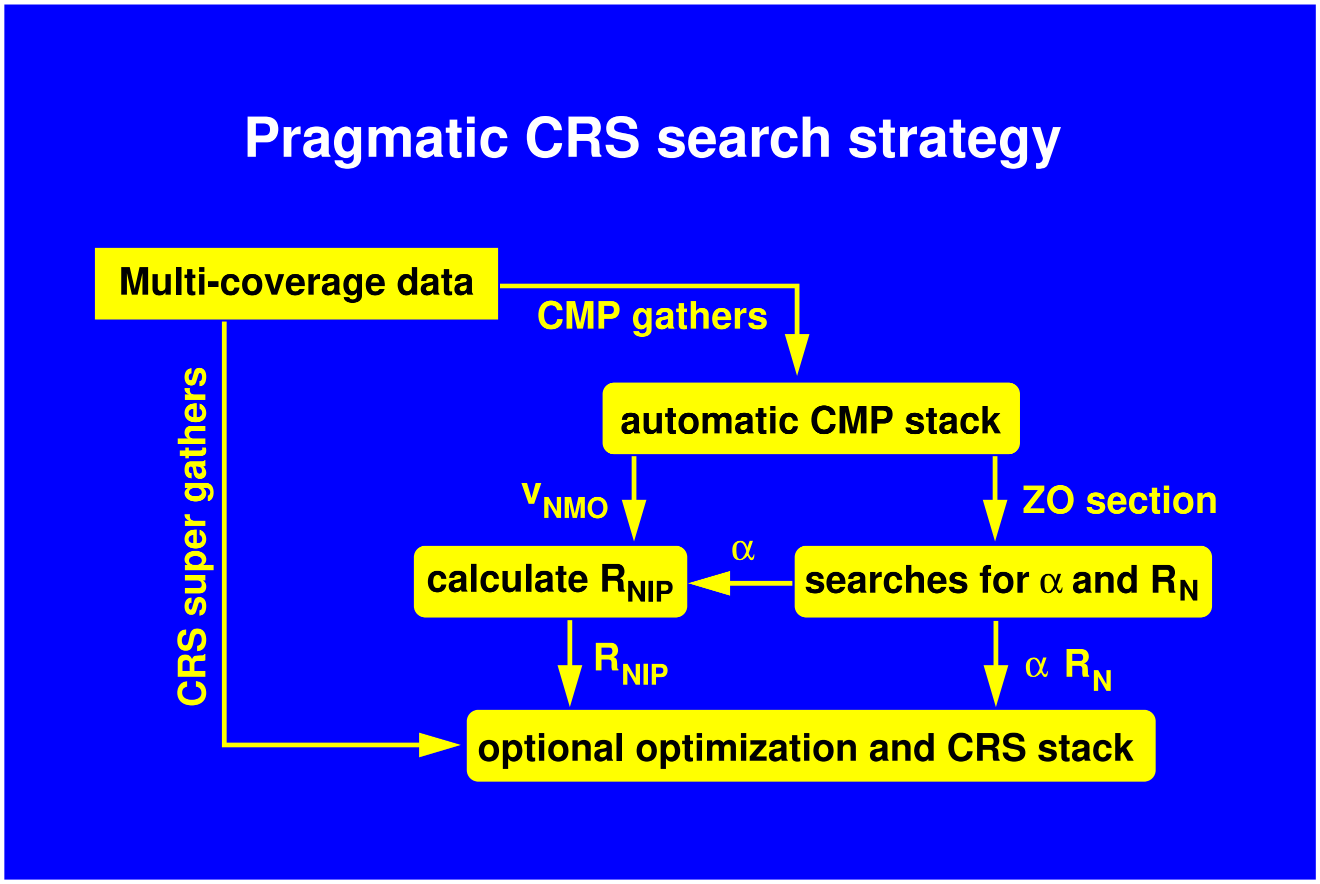
Pragmatic CRS search strategy

Common-midpoint (CMP) gather ($\Delta x = 0$):

$$t^2_{CMP}(h) = t_0^2 + \frac{4\,h^2}{v^2_{NMO}} \quad \text{with} \quad v^2_{NMO} = \frac{2\,v_0\,R_{NIP}}{t_0\,\cos^2\alpha}$$

Zero-offset section ($h = 0$):

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


Pragmatic CRS search strategy
Multi-coverage data
CMP gathers
automatic CMP stack
v_{NMO}
ZO section
calculate R_{NIP}
α
searches for α and R_N
CRS super gathers
R_{NIP}
α R_N
optional optimization and CRS stack

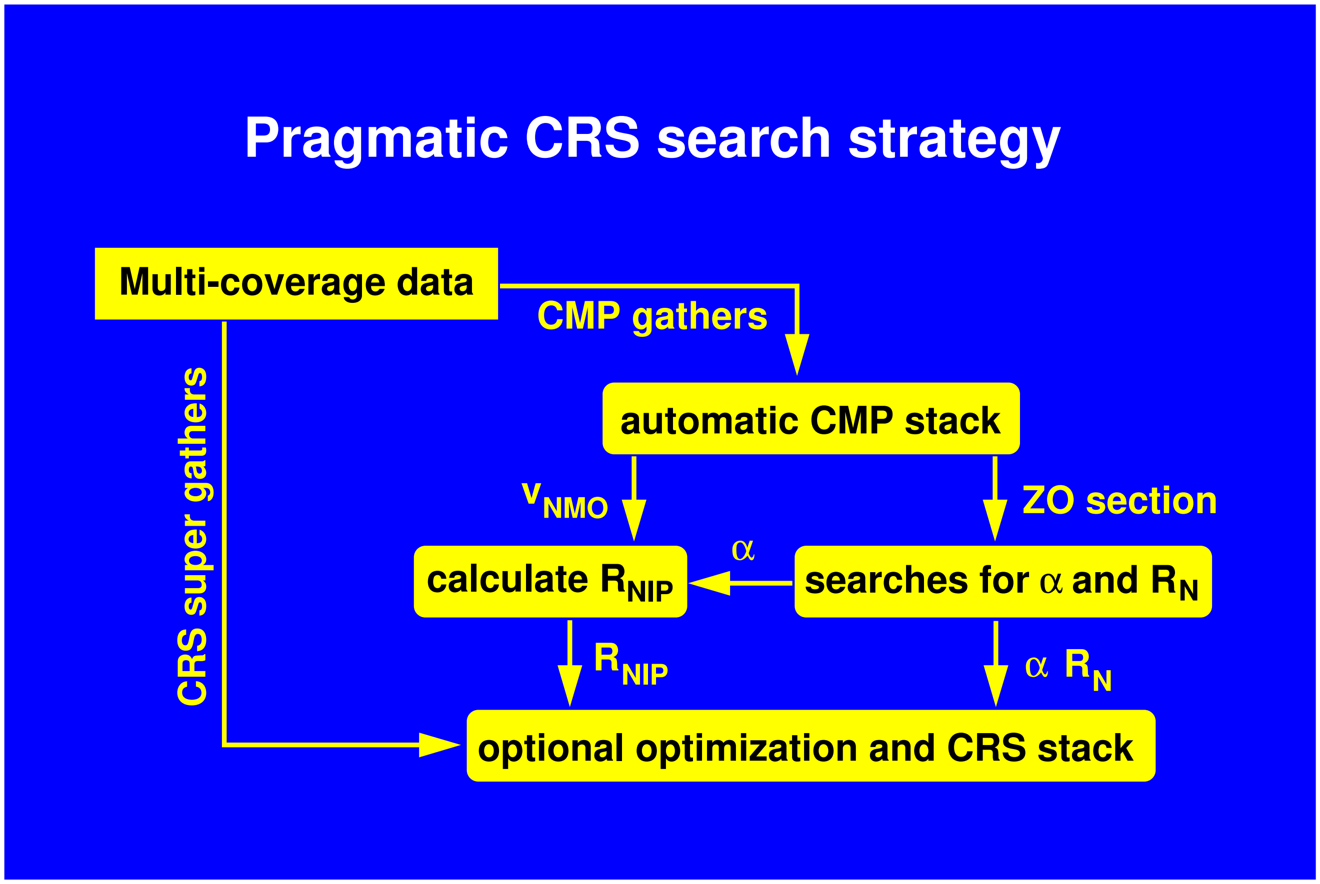
Pragmatic CRS search strategy

Benefits:

- only one-parameter searches required
- three-parameter *local* optimization is optional

Problems:

- only one stacking operator per sample
- conflicting events are suppressed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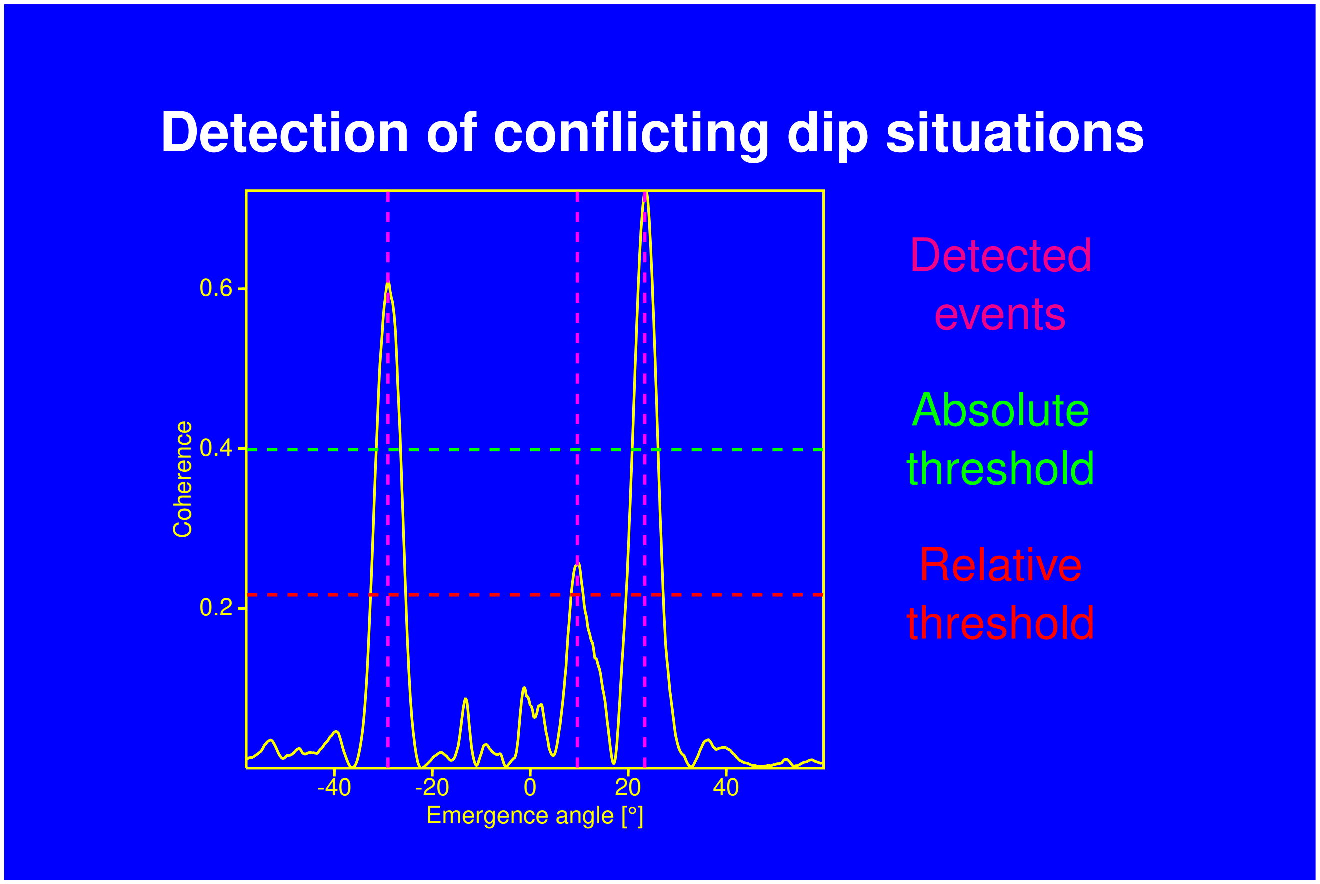
α R_N
optional optimization and CRS stack

Detection of conflicting dip situations

- CMP gathers are not suitable
- CMP stacked section provides angle spectra
- Extension of pragmatic approach readily provides $\alpha^{(i)}$ and $R_N^{(i)}$
- Problem:
  $R_{NIP}^{(i)}$ cannot be calculated from v_{NMO} and $\alpha^{(i)}$ due to ambiguity


Detection of conflicting dip situations
0.6
0.4
0.2
Coherence
-40
-20
0
20
40
Emergence angle [°]
Detected events
Absolute threshold
Relative threshold

Determination of R_{NIP}

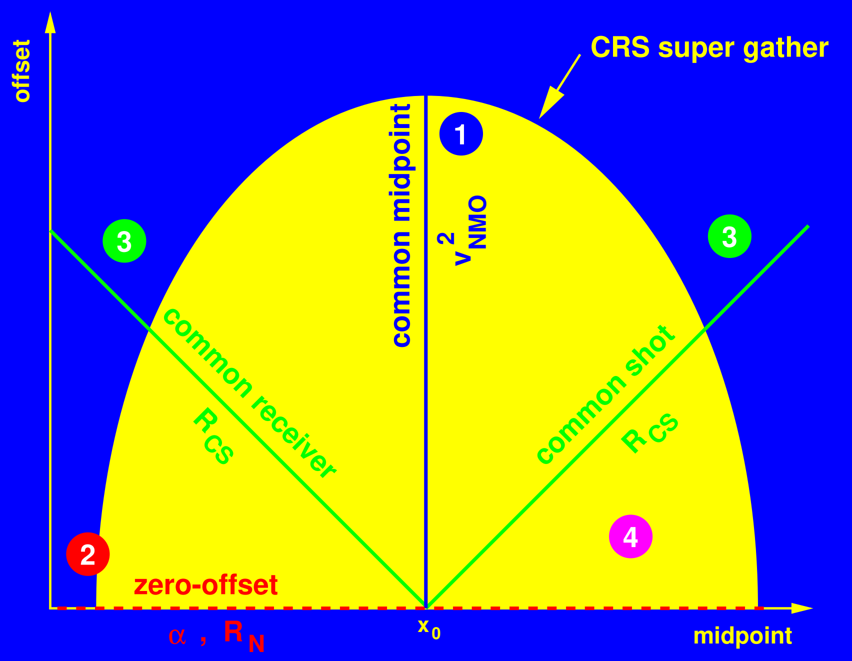
CMP gather: α and R_{NIP} not separable
ZO section: R_{NIP} does not contribute

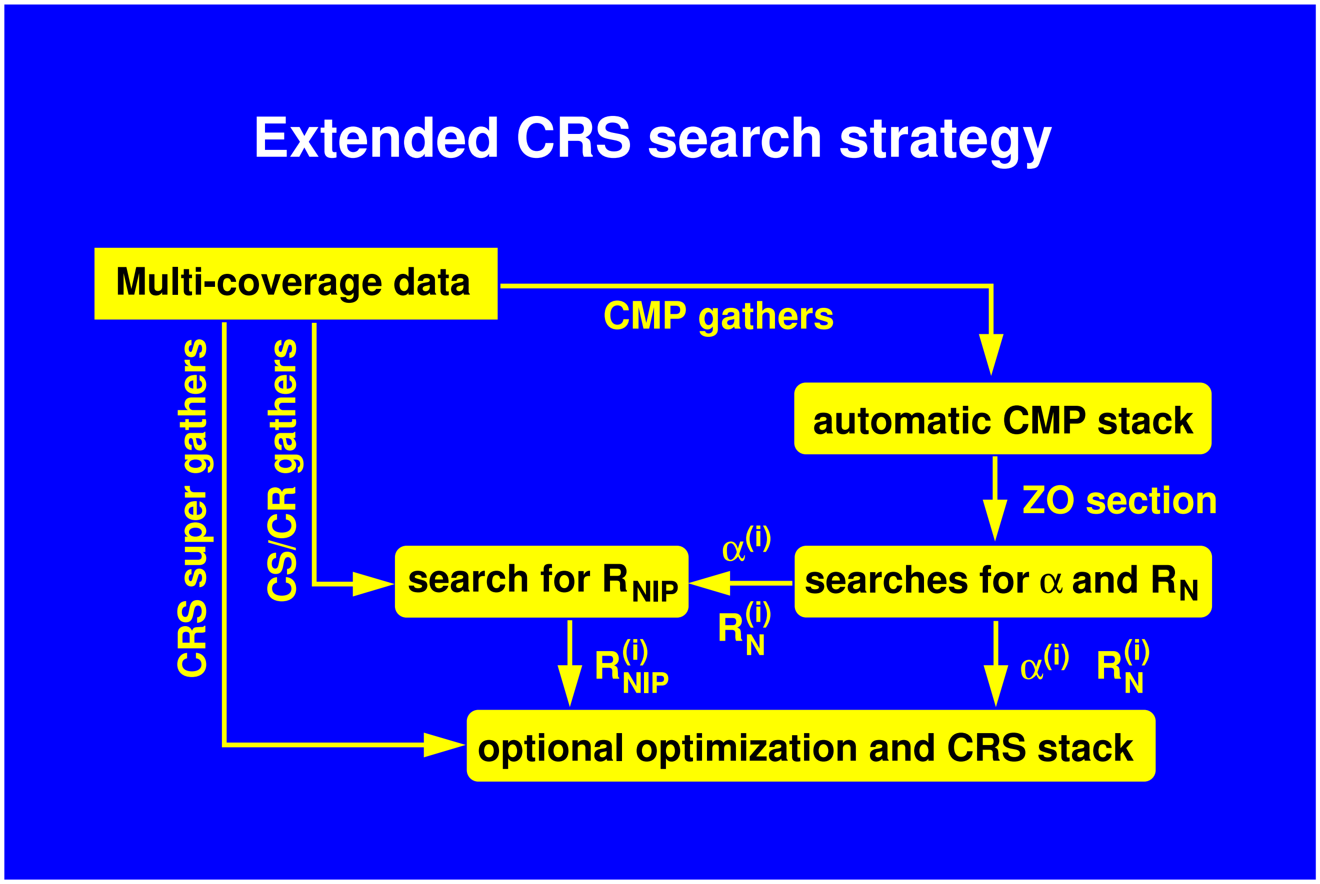
Common-shot (CS)/common-receiver (CR) gather $(|\Delta x| = |h|)$:

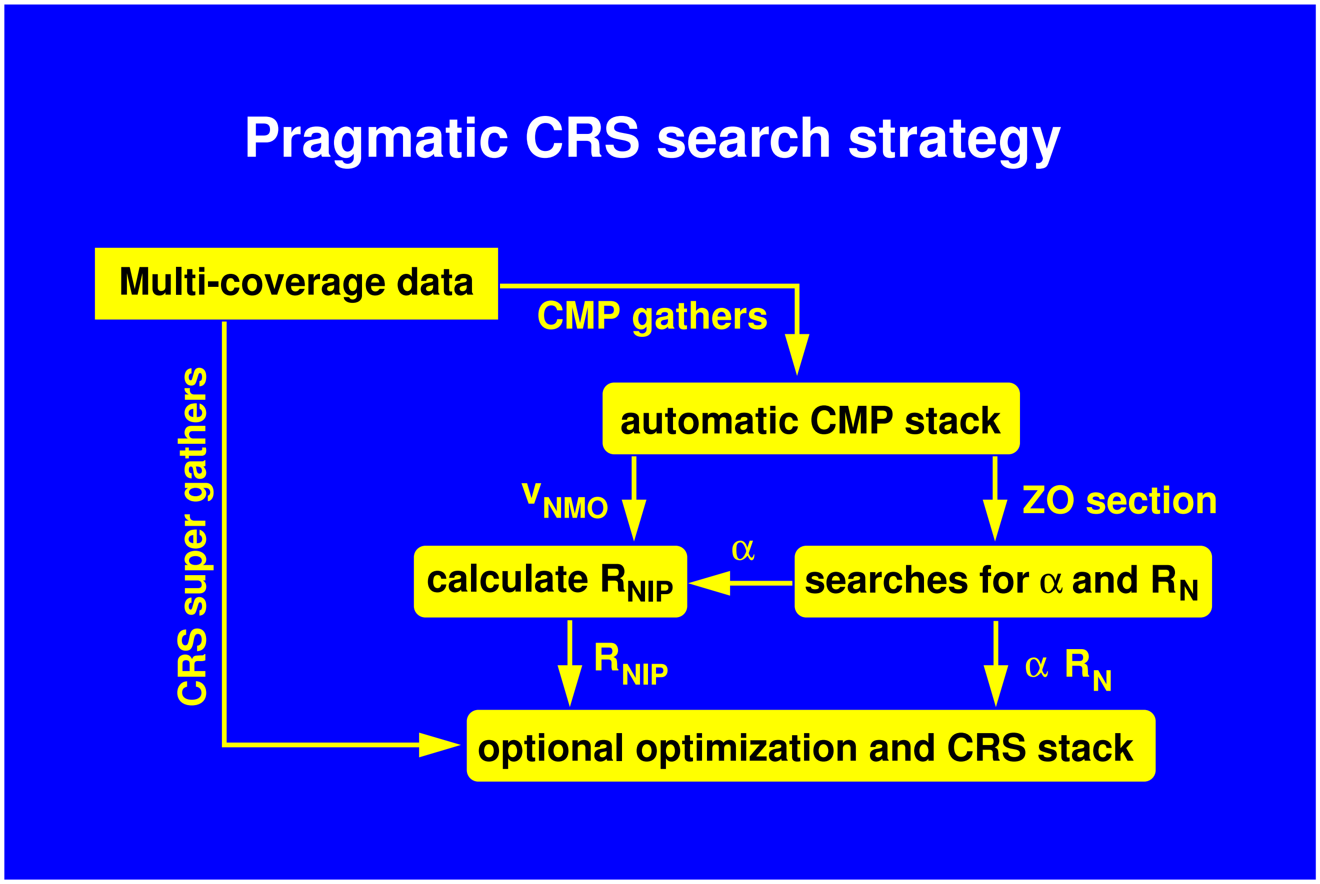
$$t_{CS}^2(\Delta x) = \left(t_0 + \frac{2\,\sin\alpha\,\Delta x}{v_0}\right)^2 + \frac{2\,t_0\cos^2\alpha\,\Delta x^2}{v_0 R_{CS}},$$

with $1/R_{CS} = 1/R_{NIP} + 1/R_N$

Determination of R_{NIP}




Extended CRS search strategy
Multi-coverage data
CMP gathers
automatic CMP stack
ZO section
CRS super gathers
CS/CR gathers
search for R_{NIP}
$\alpha^{(i)}$
$R_N^{(i)}$
searches for α and R_N
$R_{NIP}^{(i)}$
$\alpha^{(i)}$ $R_N^{(i)}$
optional optimization and CRS stack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NMO/DMO/stack vs. extended CRS stack

NMO/DMO/stack:

- Operator based on ZO isochron segment
- Summation of all possible contributing dips
- Correct DMO operator requires velocity model
- DMO provides no additional information

NMO/DMO/stack vs. extended CRS stack

Extended CRS stack:

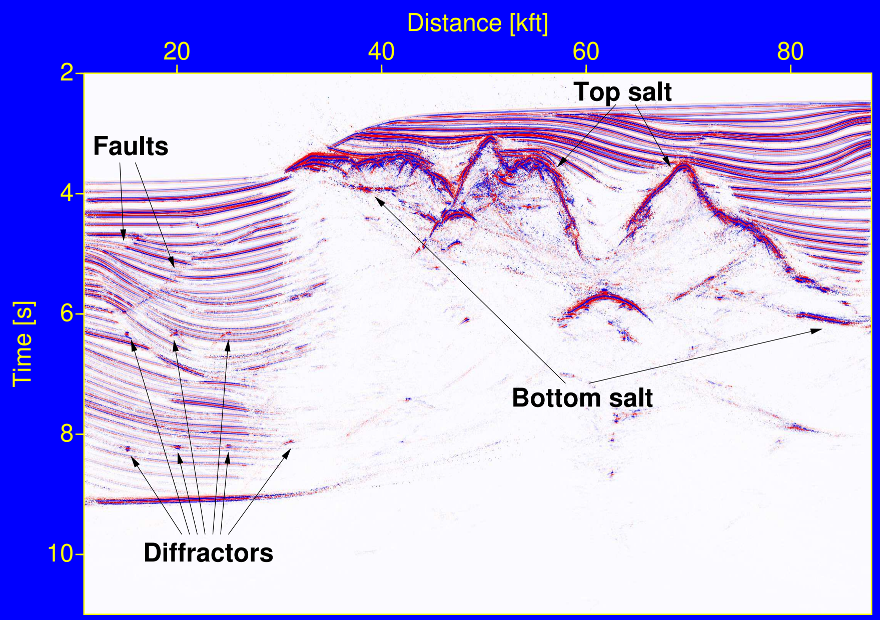
- Operator based on arbitrarily curved reflector segment
- Discrete number of contributing dips
- Data-oriented, a priori model is optional
- Separate wavefield attributes for each detected dip

Synthetic example: Sigsbee 2A data

Modeling parameters	
Number of receivers	348
Receiver interval	75 ft
Shot interval	150 ft
Sampling rate	4 ms
CMP bin distance	37.5 ft
Maximum CMP fold	87

Data courtesy of *Subsalt Multiples Attenuation and Reduction Technologies* (SMAART) joint venture

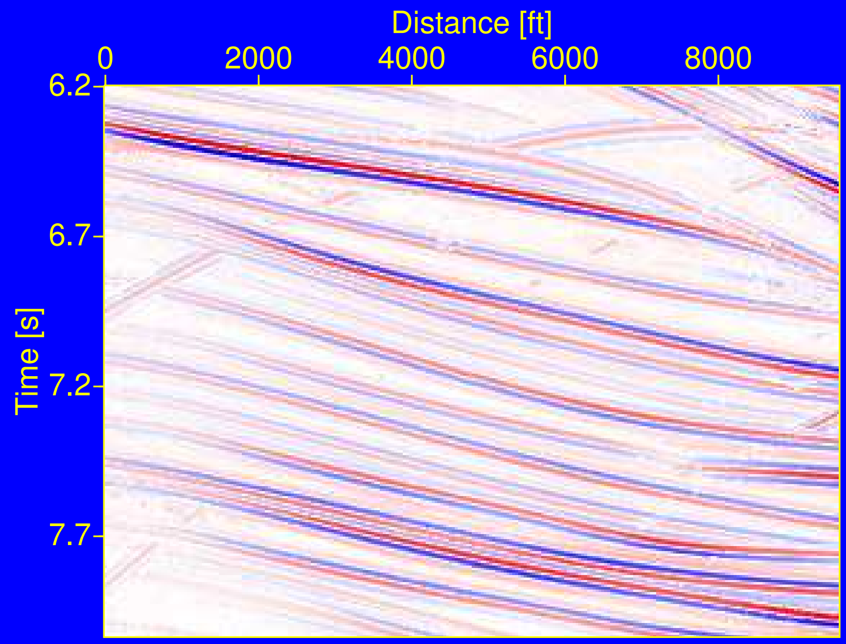
Synthetic example: Sigsbee 2A data



Macro-model independent time migration

Synthetic example: Sigsbee 2A data

Pragmatic CRS strategy



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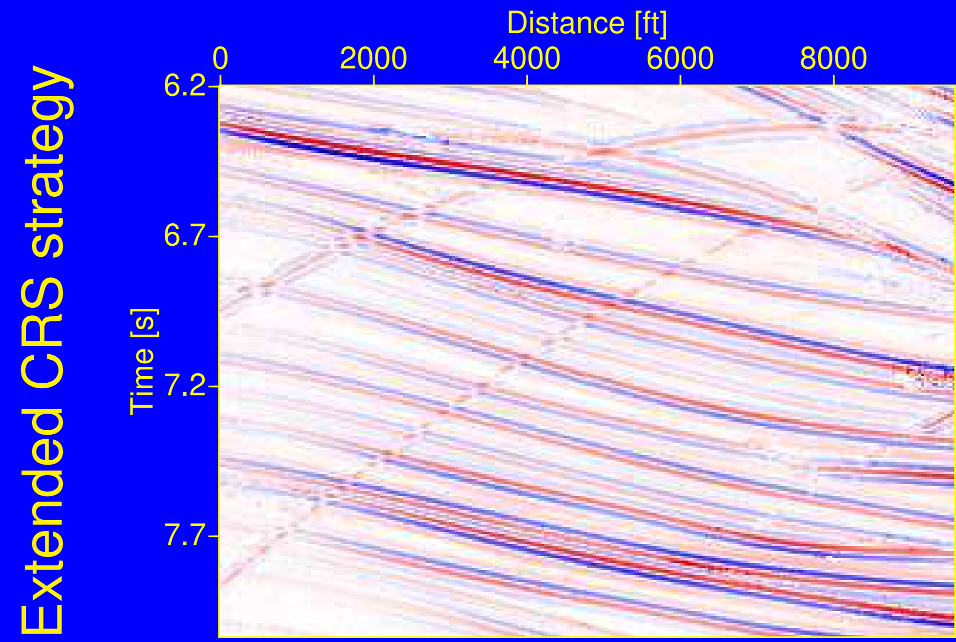
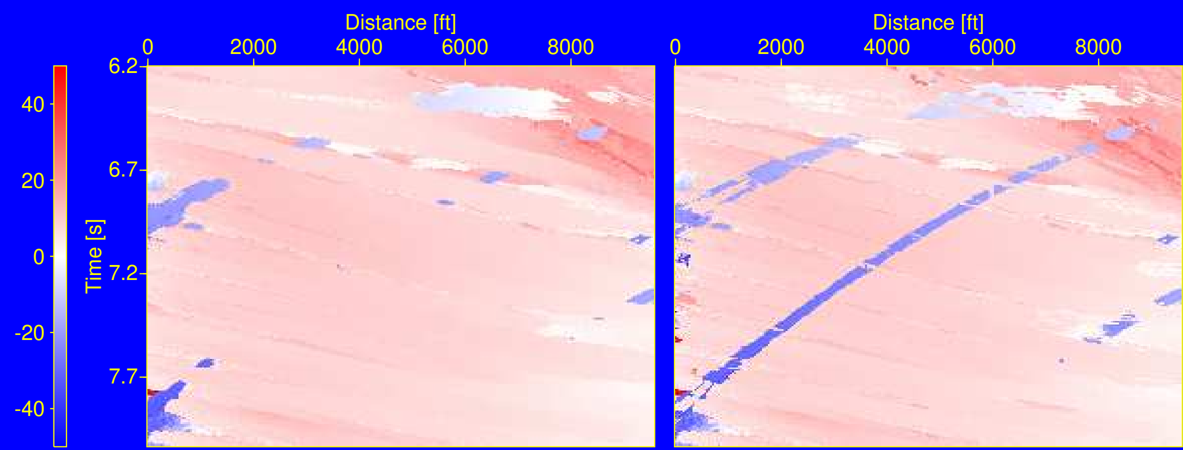


Synthetic example: Sigsbee 2A data

Detected emergence angles [°]

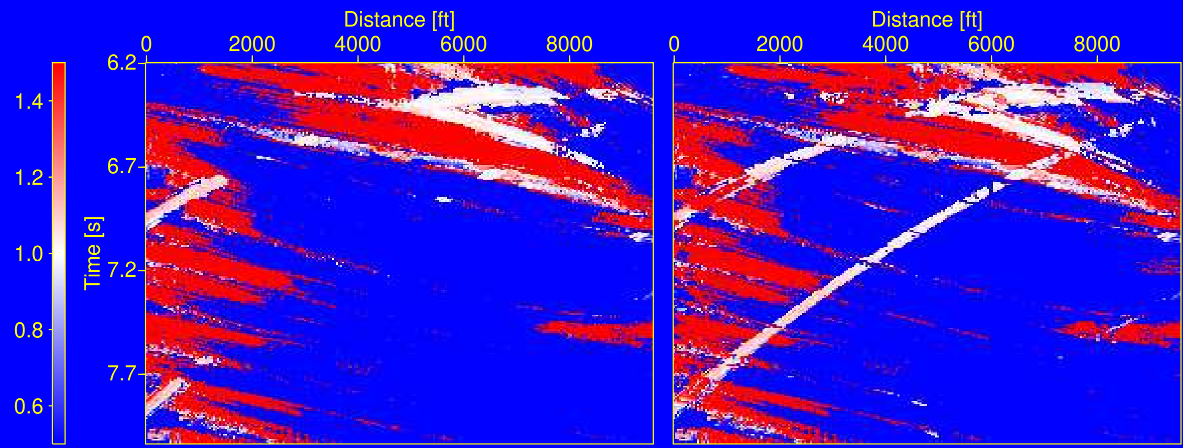


Dominant events

Conflicting events

Synthetic example: Sigsbee 2A data

Ratio of wavefront curvatures $|R_N| / R_{NIP}$



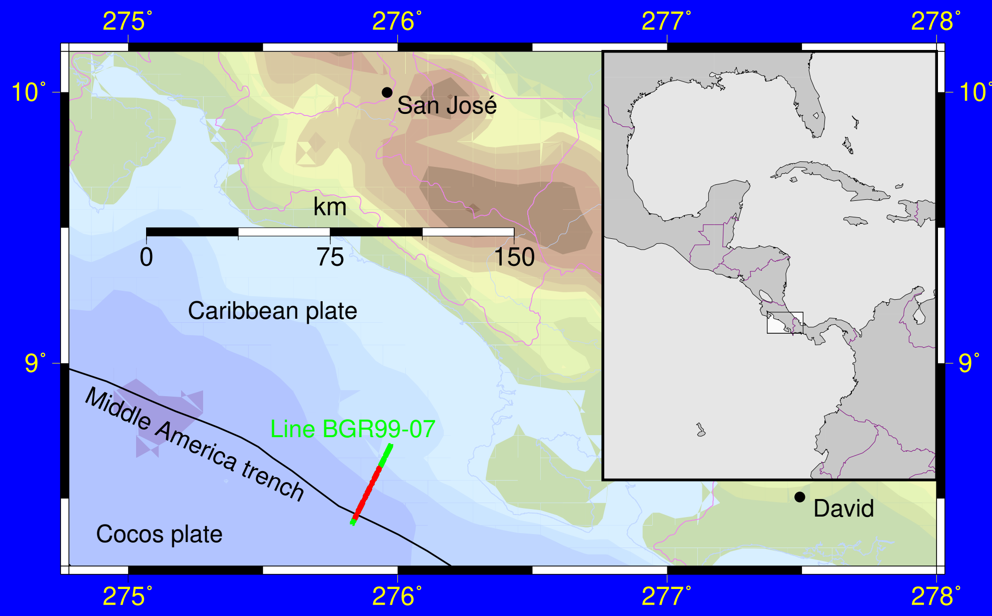
Dominant events | Conflicting events

Real example: BGR99-07 data

Acquisition parameters	
Number of receivers	360
Receiver interval	12.5 m
Shot interval	50 m
Sampling rate	4 ms
CMP bin distance	6.25 m
Maximum CMP fold	49

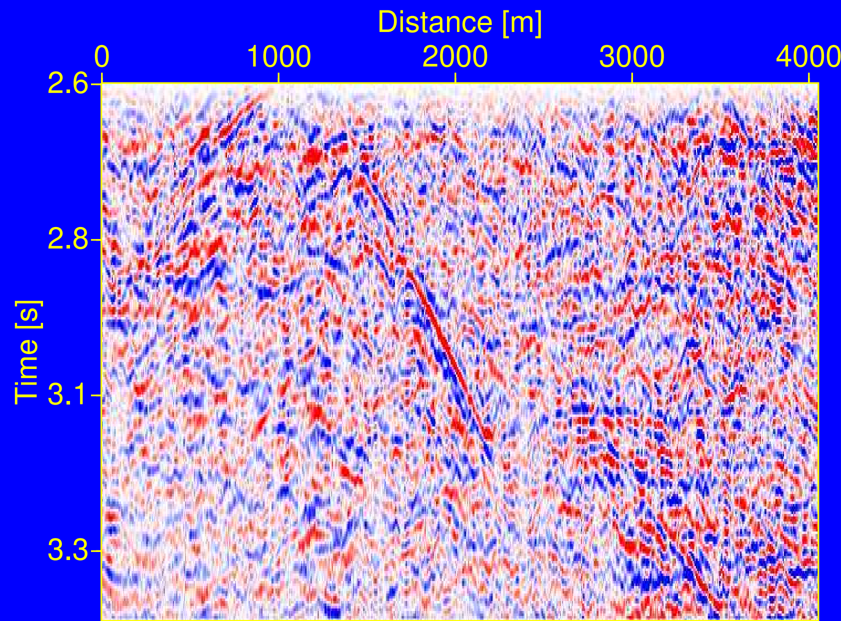
Data courtesy of *Federal Institute for Geosciences and Natural Resources*, Germany

Real example: BGR99-07 data



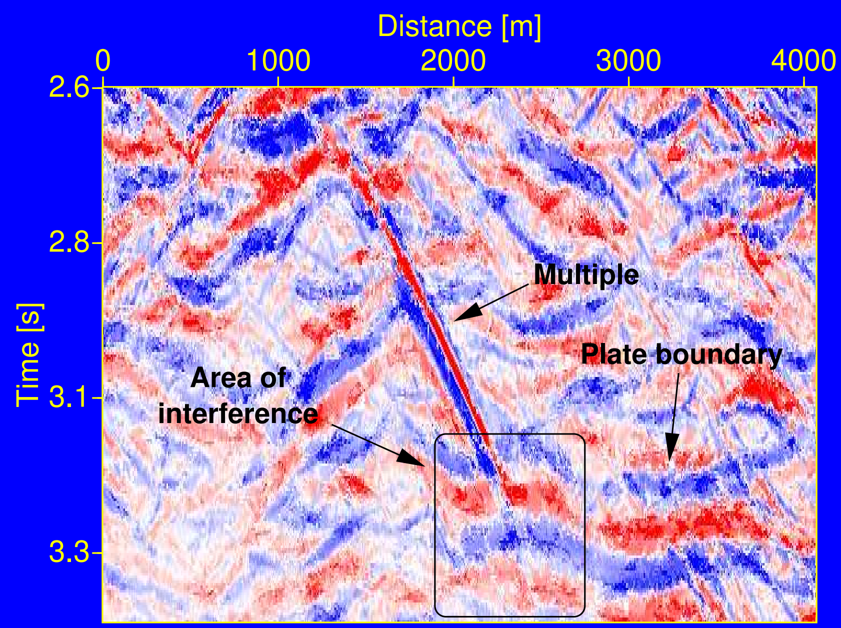
Real example: BGR99-07 data

Raw near-offset section



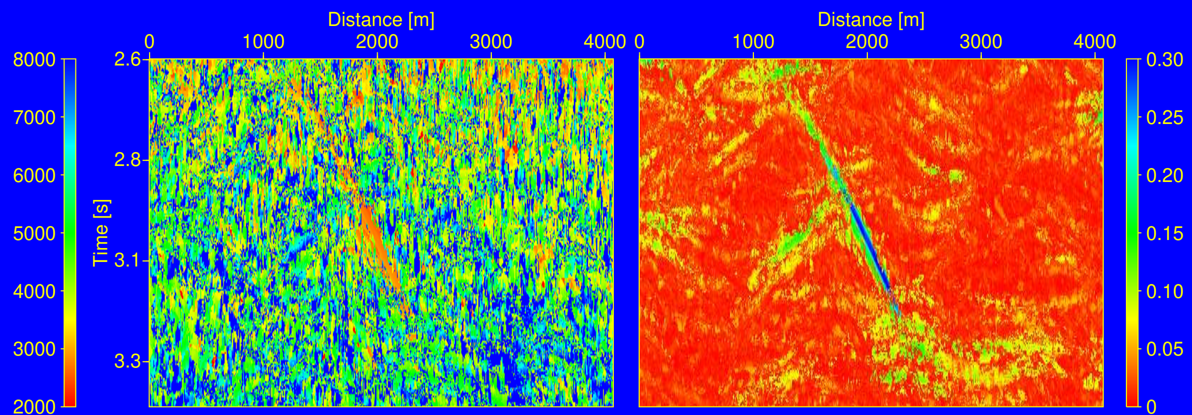
Real example: BGR99-07 data

CRS stacked section



Real example: BGR99-07 data

Attributes of the dominant events



Radius R_{NIP} [m] — Coherence

The anomaly in R_{NIP} indicates the multiple.

Conclusions (I)

Benefits:

- most conflicting dip situations are detected
- interference of events is simulated, thus ZO simulation is more realistic
- separate characterization of each event, CRS attributes available for all events
- little additional effort required

Conclusions (II)

Limitations:

- strategy relies on sufficient quality of CMP stacked section
- appropriate coherence thresholds required
- “conflicting curvature” situations not yet considered
- based on zero-order paraxial ray theory

Acknowledgments

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I would like to thank the *Subsalt Multiples Attenuation and Reduction Technologies* (SMAART) oil industry joint venture and the *Federal Institute for Geosciences and Natural Resources* (BGR), Hannover, Germany, for the data examples.

Further presentations on this topic:

Workshop W-5

Velocity Model Independent Imaging for Complex Media

on Friday, 14th