Event-consistent smoothing in generalized high-density velocity analysis

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Overview

Introduction

Smoothing algorithm

Data examples

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Acknowledgments

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Conventional stacking velocity analysis:

- (semi-)interactive, interpretative velocity picking
- coarse picks on selected key events, only

☞ human interaction required

☞ low temporal and spatial resolution

☞ pulse stretch deteriorates stack result

Thus desirable:

- automated approach
- more appropriate parameterization
- maximum resolution

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Common-Reflection-Surface (CRS) stack

Generalization of conventional approach:

- second-order approximation of traveltime
- fully automated coherence-based application
- high-density analysis
- *spatial* stacking operator

- additional stacking parameters related to 1. and 2. traveltime derivatives
  - ☞ geometrical interpretation

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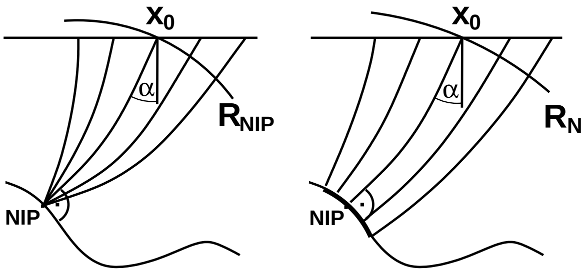
Geometrical interpretation of stacking parameters:



Emergence direction and curvatures of hypothetical wavefronts:

- exploding point source ☞ normal-incidence-point (NIP) wave
- exploding reflector ☞ normal (N) wave

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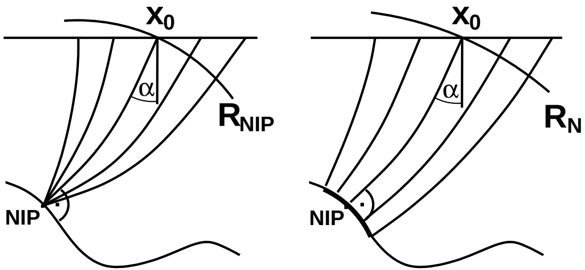

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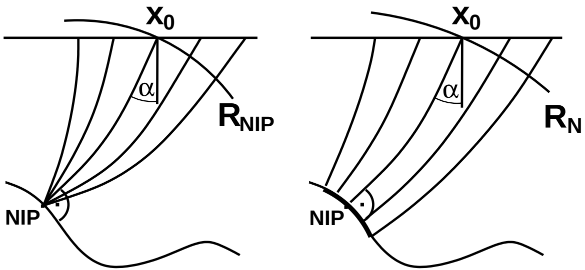

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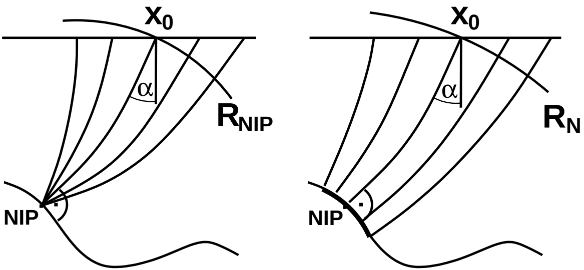

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High-density analysis vs. smoothing

Stacking parameters are subject to

- fluctuations due to noise
- outliers due to failures to detect the relevant coherence maximum

Stacking parameters represent integral properties of the subsurface

➡ smooth variation along reflection events

➡ *event-consistent* smoothing along reflection events is justified!

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Bandwidth is limited. What happens along the wavelet?

- high-density stacking velocity
  - systematic variation along wavelet
  - smoothing reintroduces pulse stretch phenomenon
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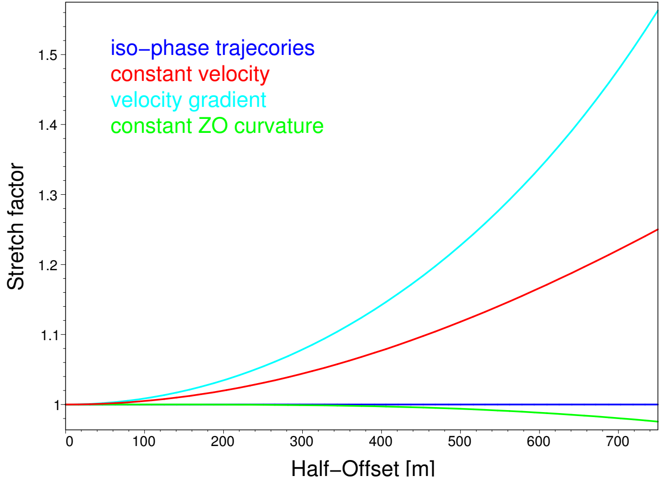
Pulse stretch phenomenon

Smooth model: stacking velocity vs. CRS parameters



From: Mann and Höcht, 2003, *Pulse stretch effects in the context of data-driven imaging methods*, 65th Conf., Eur. Assn. Geosci. Eng.

Smoothing algorithm

Requirements:

- smoothing along reflection events justified ✔
- smoothing along wavelet justified
- remaining task: ensure event consistence

CRS stack provides:

- local shape of zero-offset reflection event (α, R_N)
- approximation of projected Fresnel zone
- coherence values as measure of reliability

☞ this allows a simple and efficient smoothing algorithm

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For each zero-offset sample and each CRS parameter

- align smoothing window along reflection event using emergence angle α (optionally also R_{N})
- reject samples below given coherence threshold ☞ use only reliable attributes
- reject samples with dip difference beyond threshold ☞ avoid mixing of intersecting events
- apply combined filter:
- assign result to zero-offset sample

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Size of smoothing window:

- as small as possible, as large as required
- temporal extension $\leq$ wavelet length
- lateral extension $\ll$ projected Fresnel zone, either fixed or a fraction of approximate Fresnel zone given by CRS parameters

Smoothing in the 3D case:

- smoothing window is a small volume
- same selection criteria as in 2D
- combined filter has to be generalized for curvature matrices and slowness vectors
  - ☞ current research

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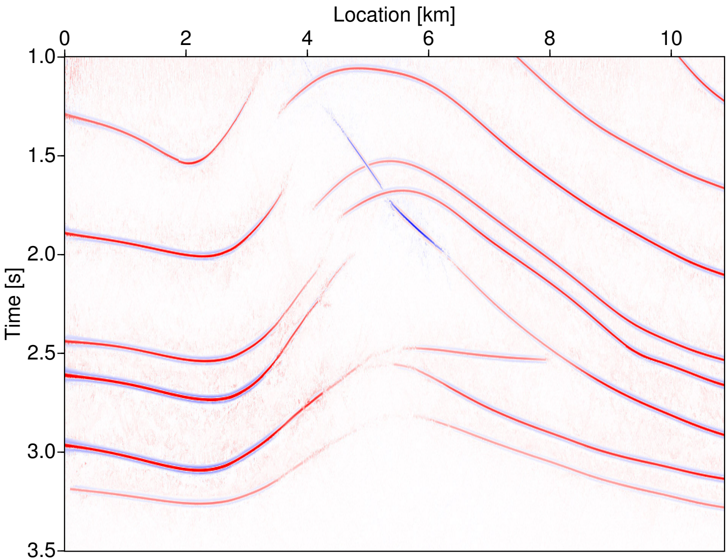
Schematic example



CRS stack section

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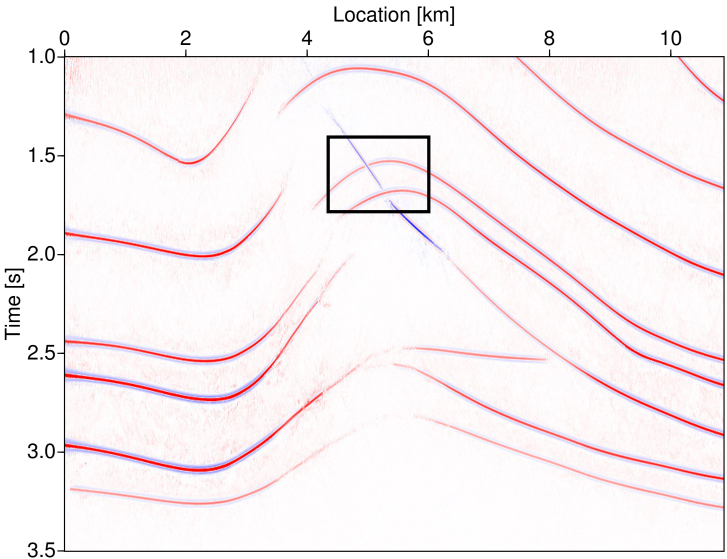

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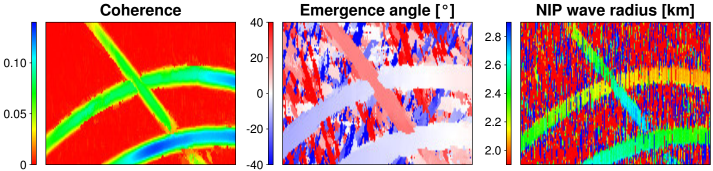

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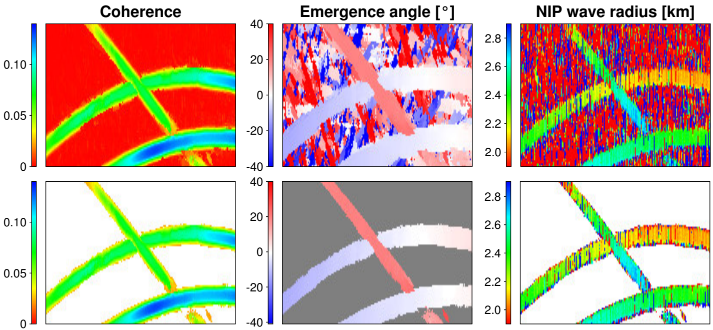

Coherence-based mask applied
(for visualization, only)

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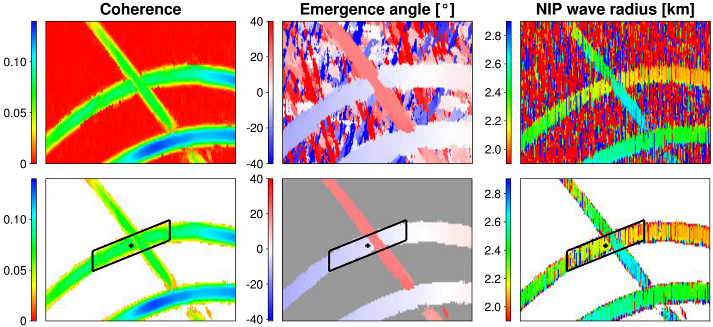
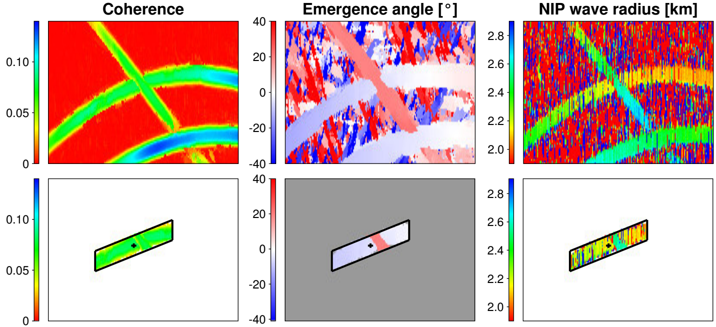


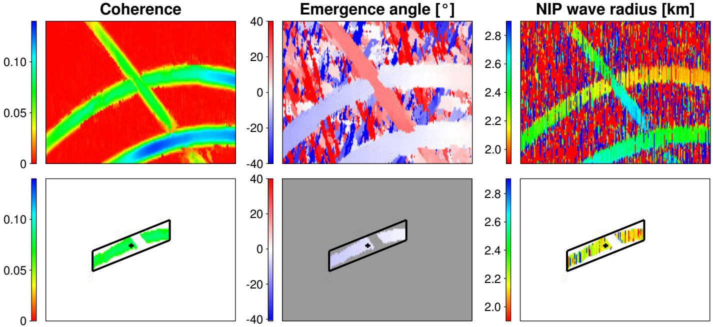
Smoothing window aligned with reflection event

Schematic example



Select all samples in window

Schematic example



Apply coherence threshold and
dip difference threshold

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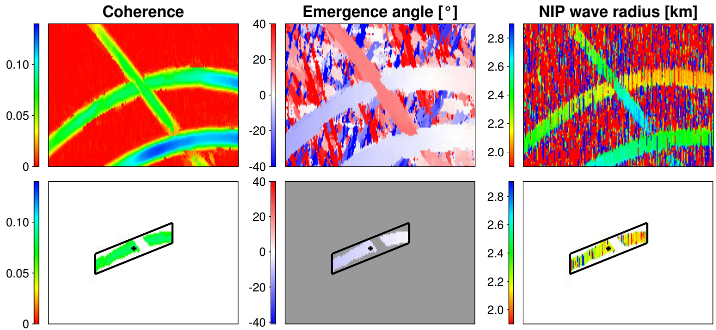
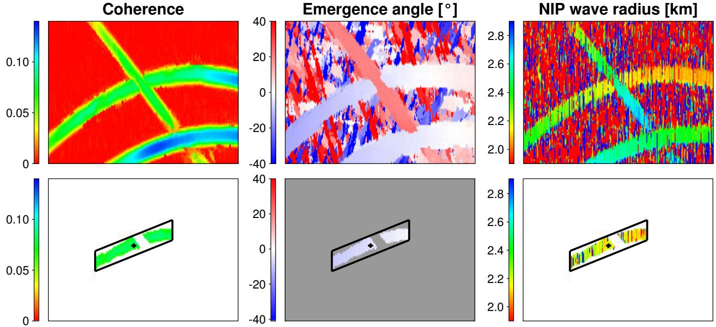


Smoothing:

- Sort remaining samples by magnitude

Schematic example



Smoothing:

- Sort remaining samples by magnitude
- Average given fraction of samples around median

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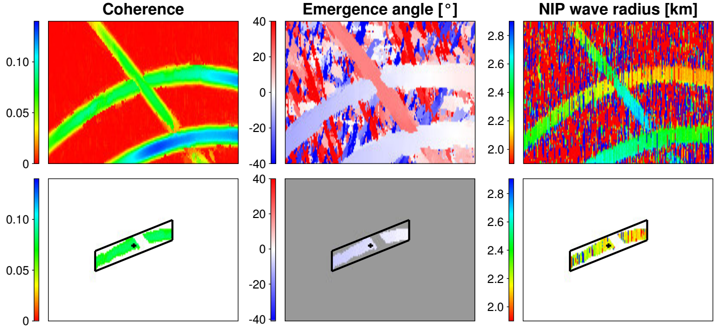
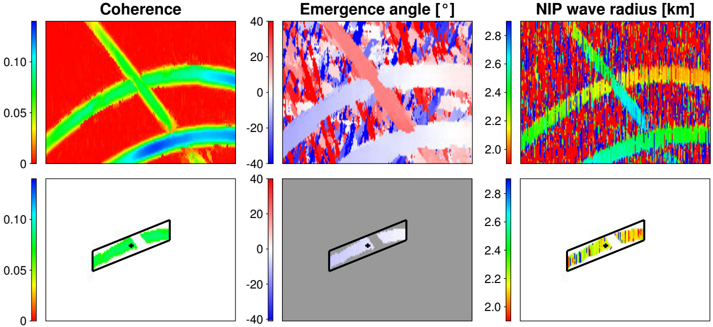


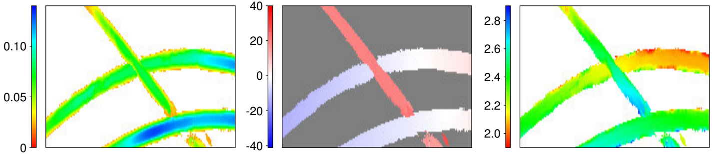
Smoothing:

- Sort remaining samples by magnitude
- Average given fraction of samples around median
- Assign result to considered ZO location

Schematic example



Repeated for all location ☞ smoothed attribute sections



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SEG, Denver 2004
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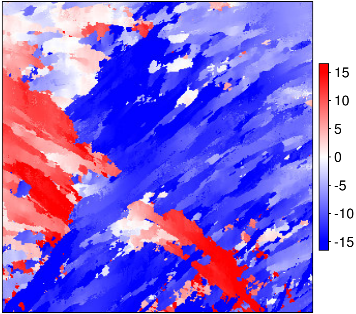
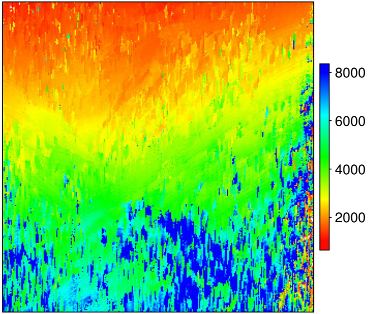
Real data example

CRS parameter sections (detail)



Emergence angle [°]

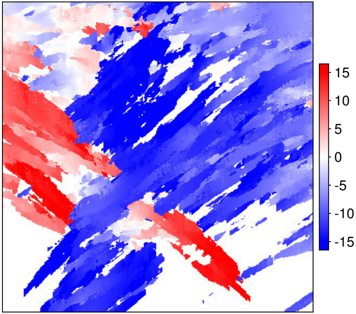


NIP wave radius [m]

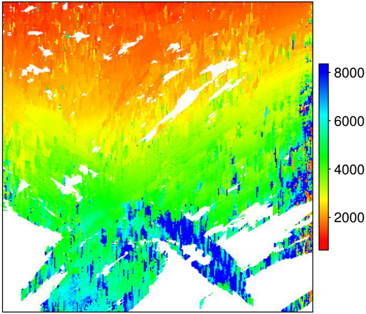
Original parameters as obtained by CRS stack
(no coherence mask applied)

Real data example

CRS parameter sections (detail)



Emergence angle [°]

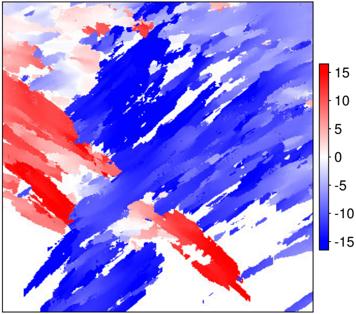


NIP wave radius [m]

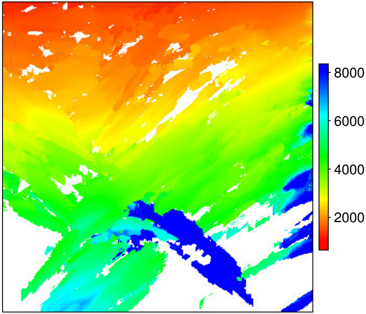
Original parameters as obtained by CRS stack
(coherence mask applied for display, only)

Real data example

CRS parameter sections (detail)



Emergence angle [°]

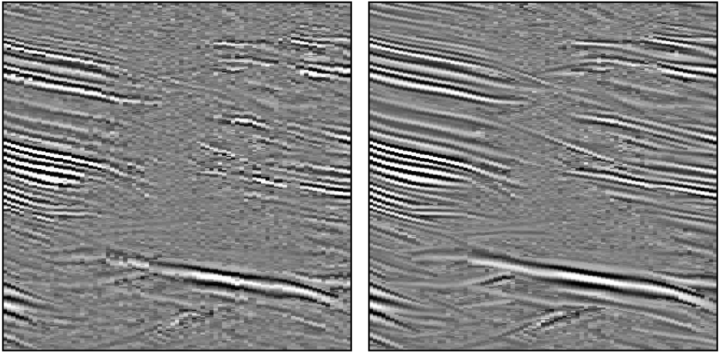


NIP wave radius [m]

Smoothed parameters
(coherence mask applied for display, only)

Real data examples

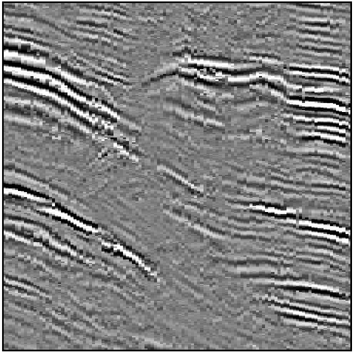
CRS stack sections (detail I)

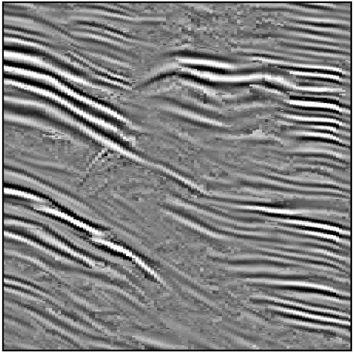


Stack with original vs. stack with smoothed parameters

Real data examples

CRS stack sections (detail II)





Stack with original vs. stack with smoothed parameters

Conclusions

Smoothing algorithm:

- event-consistent smoothing
- based on CRS stacking parameters and coherence
- removes outliers
- removes fluctuations
- preserves kinematic properties of reflection events
- avoids mixing of intersecting events

➥ improved quality of stacked section

➥ more physical CRS stacking parameter sections for various applications like macromodel determination etc.

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Acknowledgments

This work was kindly supported by the sponsors of the Wave Inversion Technology (WIT) Consortium, Karlsruhe, Germany

Related presentations

Session SP 4, Thursday morning:

SP 4.4 A seismic reflection imaging workflow based on the common-reflection-surface (CRS) stack: theoretical background and case study

SP 4.5 CRS imaging and tomography versus PreSDM: a case history in overthrust geology

SP 4.6 CRS stack and redatuming for rugged surface topography: a synthetic data example

SP 4.8 3D focusing operator estimation using sparse data