Event-consistent smoothing and automated picking in CRS-based seismic imaging

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Overview

Introduction

3D Common-Reflection-Surface (CRS) stack

Velocity determination with 3D CRS attributes

CRS-based workflow

The event-aligned volume

Event-consistent smoothing

Automated picking

Results

Conclusions

Introduction

- The Common-Reflection-Surface (CRS) stack provides
  - high S/N stacked ZO volume
  - coherence value for each sample
  - kinematic wavefield attributes for each sample
  - ➥ generalised, high density stacking velocity analysis
- The CRS attributes can further be used for many applications, e. g.:
  - calculation of projected Fresnel zone and geometrical spreading factor
  - improved AVO-analysis
  - tomographic determination of macro-velocity models

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  - outliers
  - non-physical fluctuations

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  Tomographic determination of macro-velocity models using CRS-attributes

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CRS tomography

- Advantages:
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  - pick locations independent of each other
  - very few picks required
- Quality of result depends on quality of input CRS attributes

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CRS – stack

Smoothing

optional restacking

automated picking

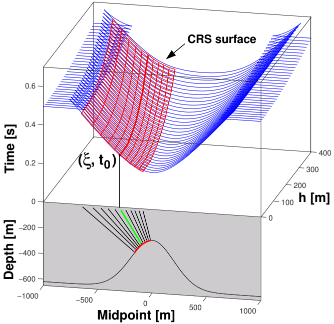
NIP–wave tomography

Migration

3D CRS attributes

Traveltime depends on eight attributes:

$$t^2(\Delta\boldsymbol{\xi},\mathbf{h}) = \left(t_0 + 2\,\mathbf{p}_\xi \cdot \Delta\boldsymbol{\xi}\right)^2 + 2t_0\left(\Delta\boldsymbol{\xi}^T \mathbf{M}_\xi\, \Delta\boldsymbol{\xi} + \mathbf{h}^T \mathbf{M}_h\, \mathbf{h}\right)$$



$$\mathbf{p}_\xi = \frac{1}{v_0}(\sin\alpha\cos\psi, \sin\alpha\sin\psi)^T$$

$$\mathbf{M}_h = \frac{1}{v_0}\mathbf{D}\mathbf{K}_{\mathrm{NIP}}\mathbf{D}^T$$

$$\mathbf{M}_\xi = \frac{1}{v_0}\mathbf{D}\mathbf{K}_{\mathrm{N}}\mathbf{D}^T$$

NIP: normal incidence point

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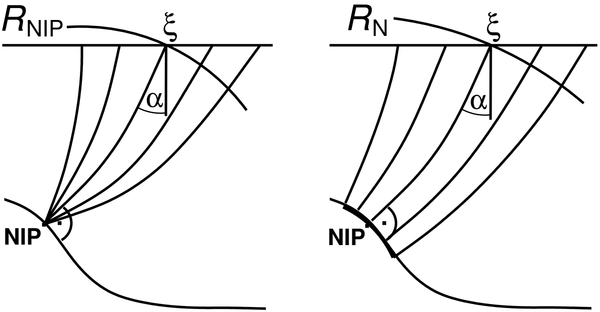
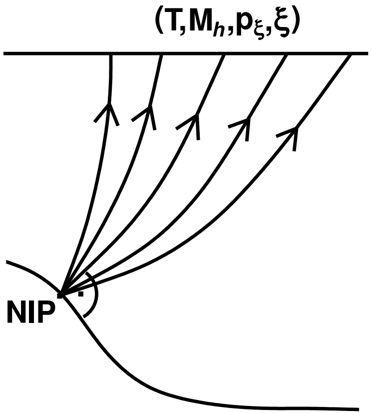
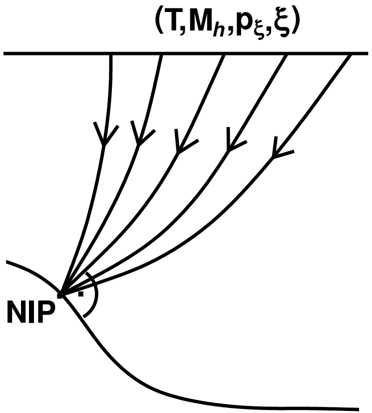


NIP waves and velocities



CRS attributes $\mathbf{M}_h$ and $\mathbf{p}_\xi$ at $(t_0, \boldsymbol{\xi})$ describe second-order traveltime approximation of emerging NIP wave.

NIP waves and velocities



In consistent velocity models, NIP waves focus at zero traveltime.

Tomography with CRS attributes

Find a velocity model in which all considered NIP waves, described by kinematic wavefield attributes, are correctly modelled.

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Remark:
in 3D, $\mathbf{M}_h$ is only required for one azimuth.

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- manual picking is very time consuming, especially in 3D

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- How to remove outliers and fluctuations in the attributes?
- Where to pick the limited number of locally coherent reflection events needed in NIP-wave tomography?
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- CRS – stack
- Smoothing
- optional restacking
- automated picking
- NIP–wave tomography
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Strategy

smoothing and picking in volumes aligned with reflection events:

- volume size defines locality
- usage of locally valid statistics

➥ to remove outliers and fluctuations

➥ to identify valid pick locations

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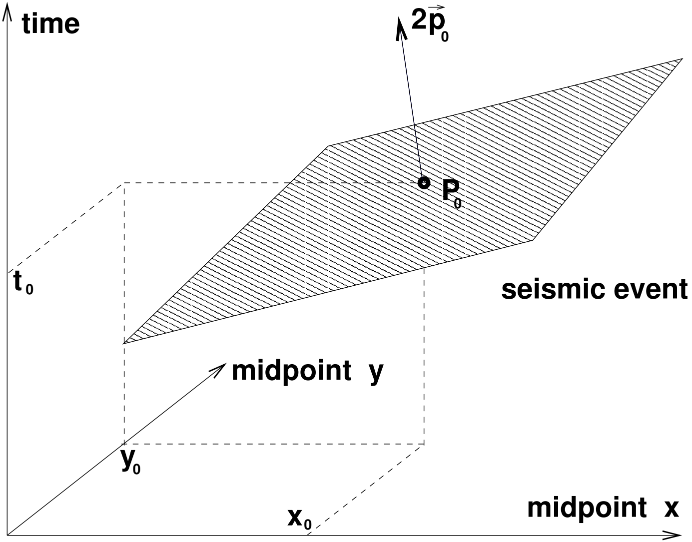

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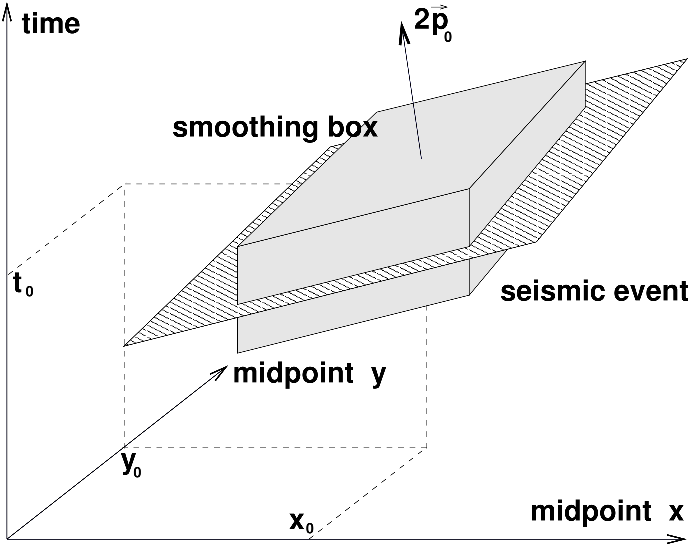

Detection of intersecting events

slowness vector:

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event discrimination by dip difference:

$$\theta = \arccos(\mathbf{n}_1 \cdot \mathbf{n}_2) \, .$$

Event-consistent smoothing

For each zero-offset sample and CRS-parameter:

- align smoothing volume with reflection event using first traveltime derivatives
- reject samples below user-defined coherence threshold
- reject samples with dip difference beyond user-defined threshold
  - ➥ avoid mixing of events
- apply combined filter:
  - median filter ➥ remove outliers
  - averaging ➥ remove fluctuations
- assign result to zero-offset sample

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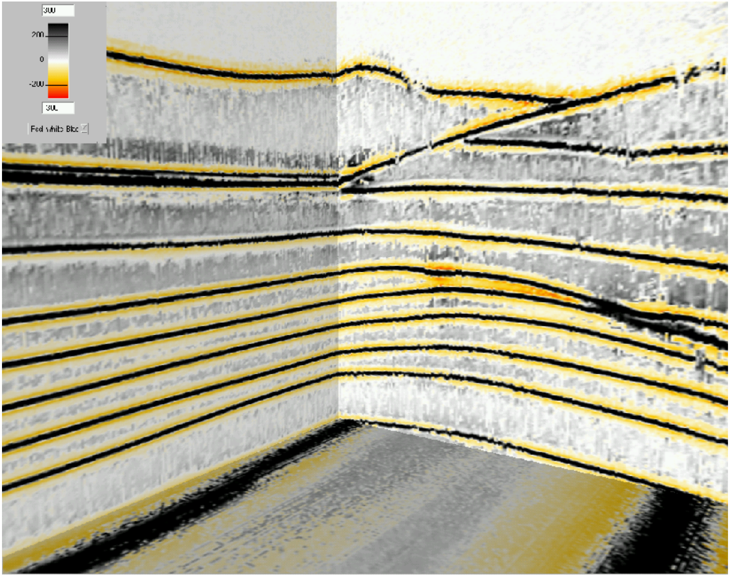
Stack, unsmoothed attributes



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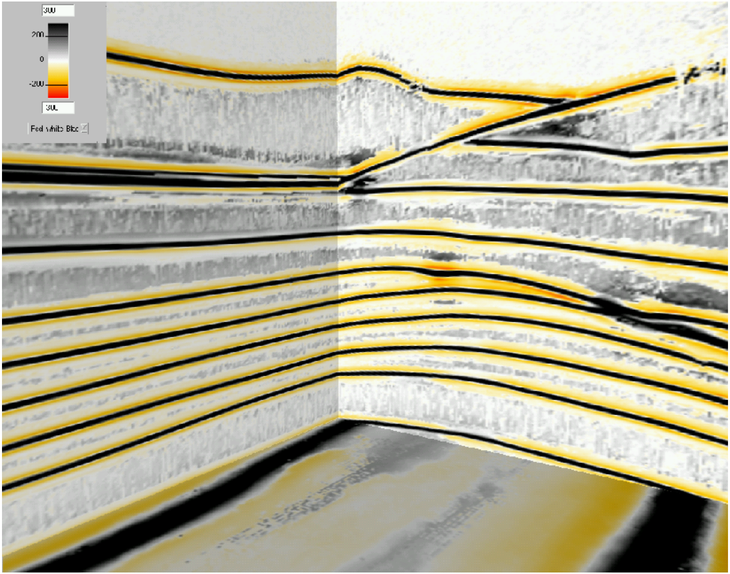

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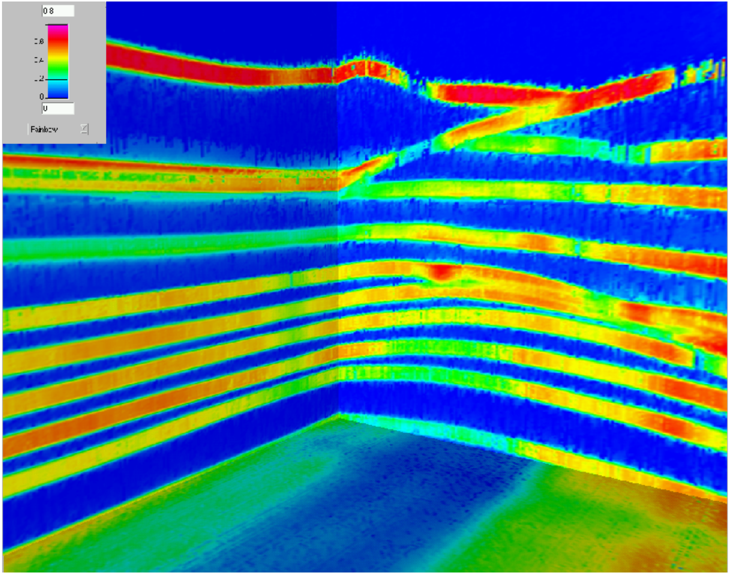

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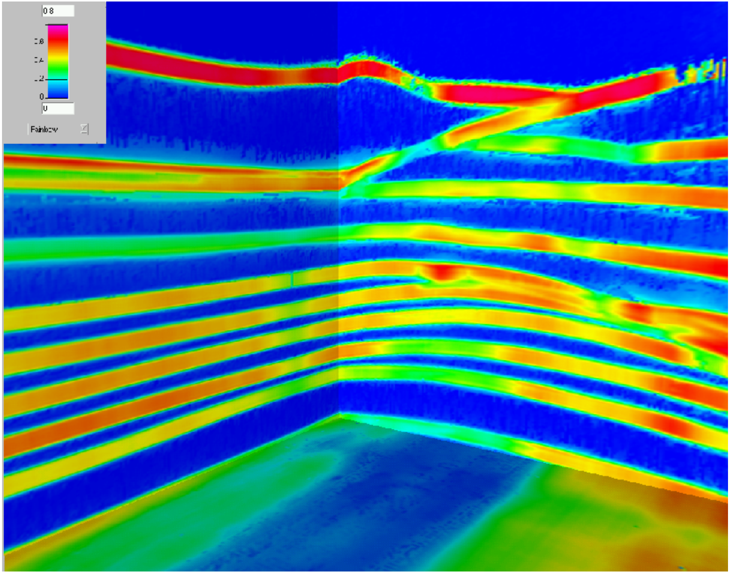

Automated picking

For each selected trace

- search (next) coherence maximum
- get nearest maximum of stack envelope
- align volume with reflection event using first traveltime derivatives
- reject pick if user-defined percentage of all samples inside the volume
  - is below a given coherence threshold or
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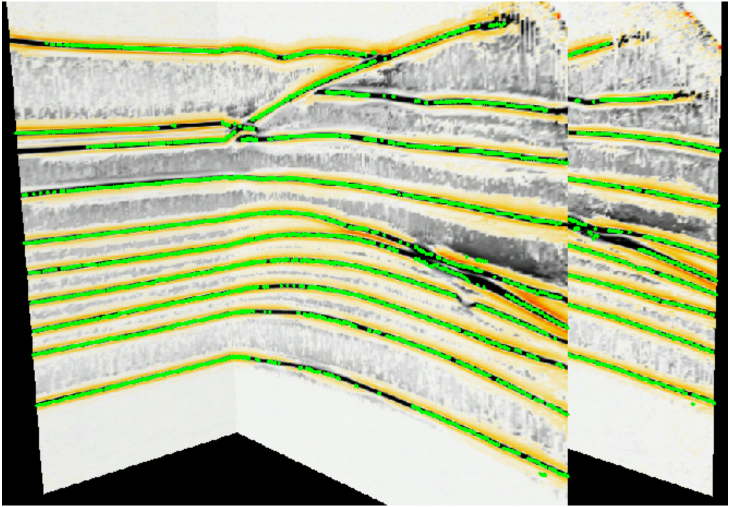
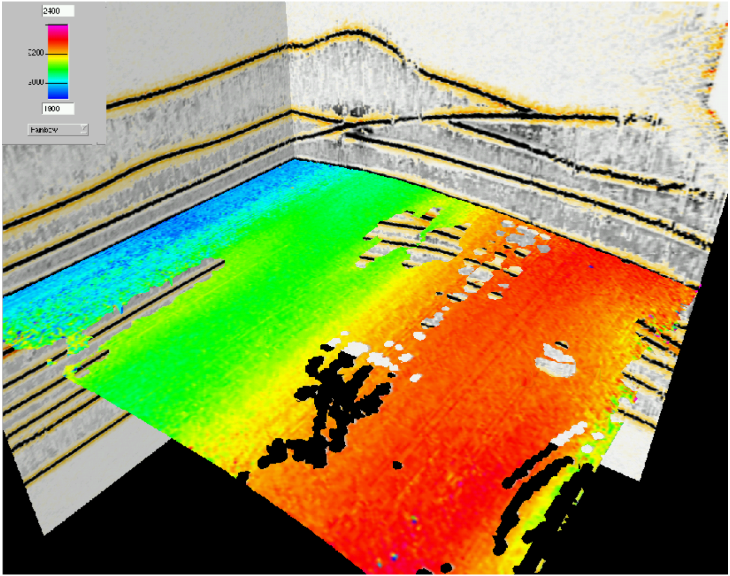
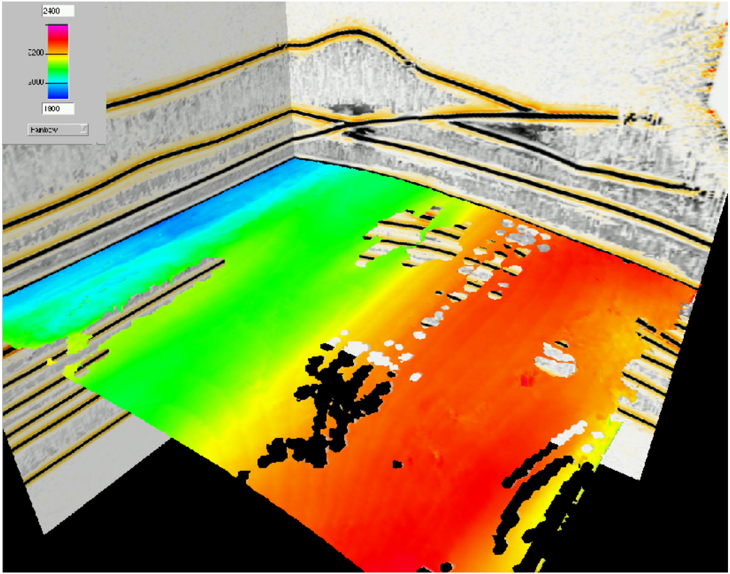
Picks on selected sections



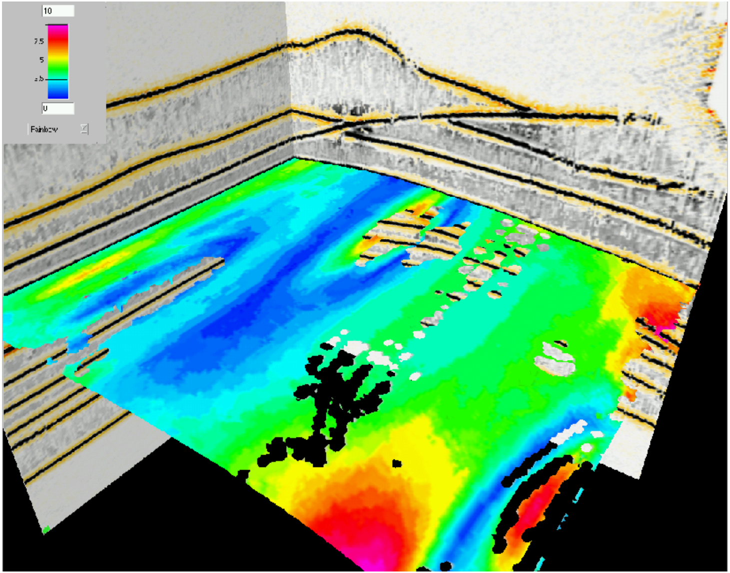
Stacking velocity



“Smoothed” stacking velocity



Normal ray emergence angle



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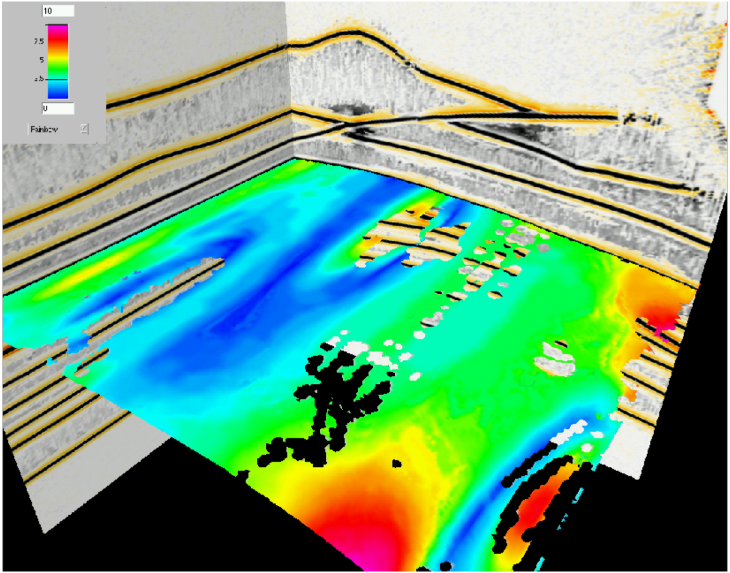

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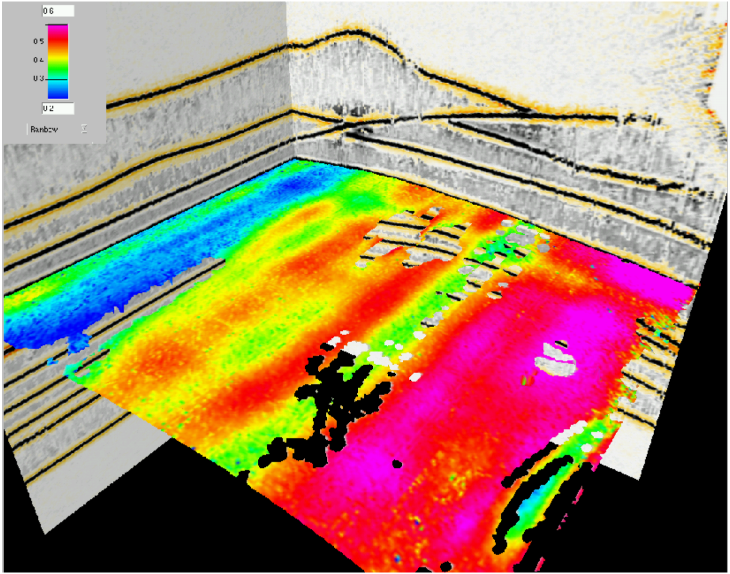
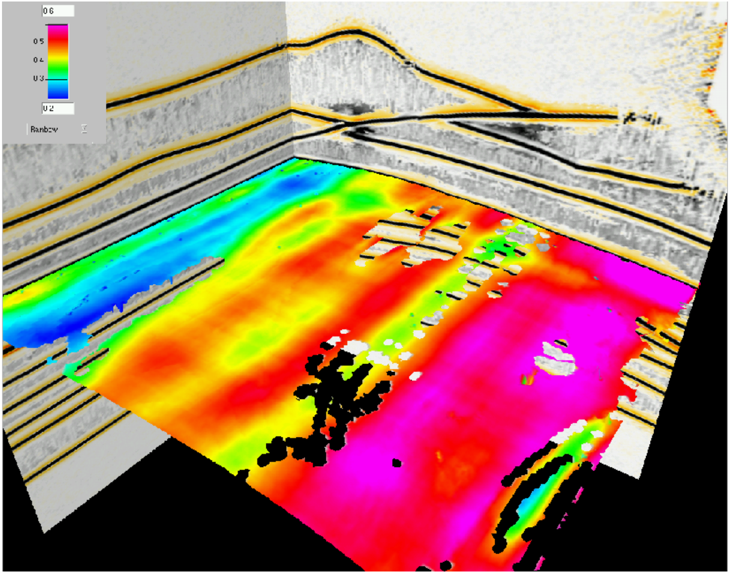


Coherence, smoothed attributes



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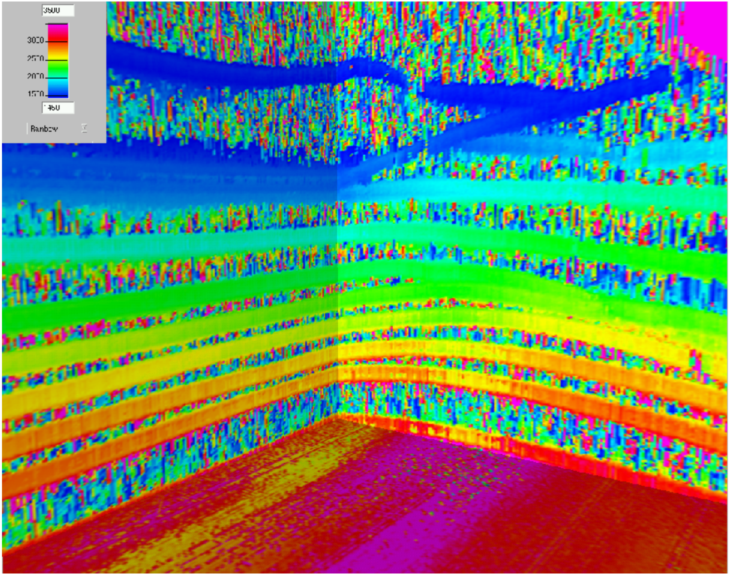

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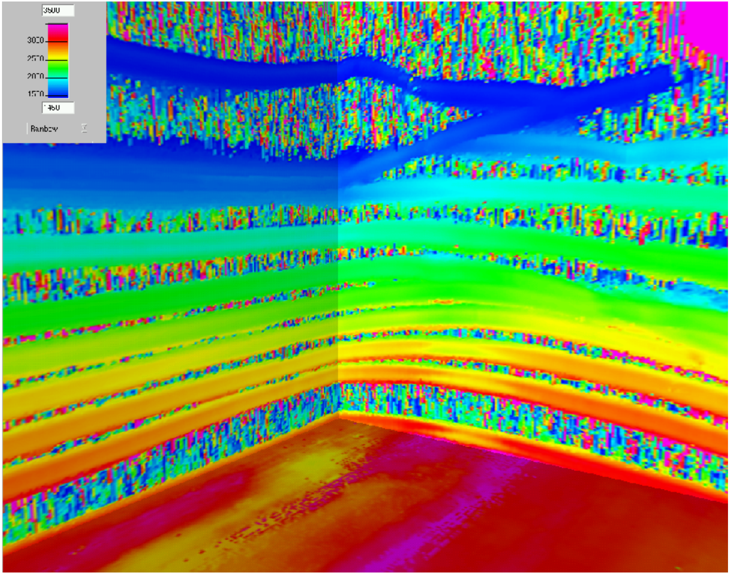

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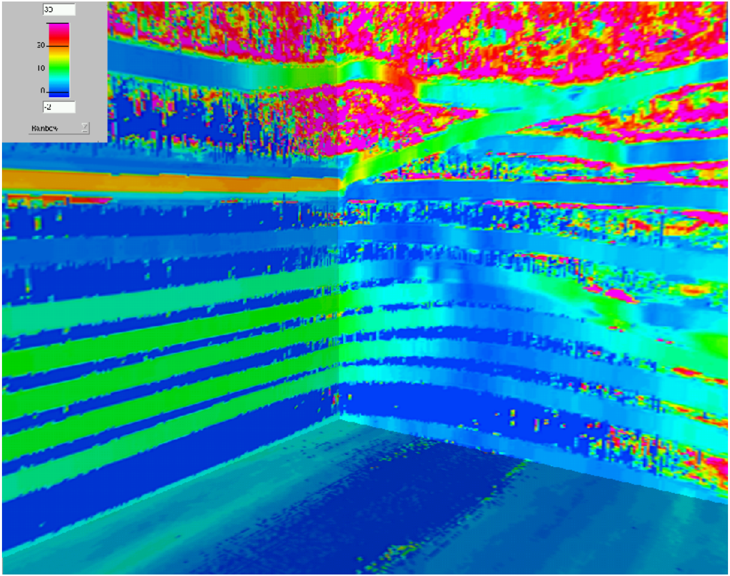

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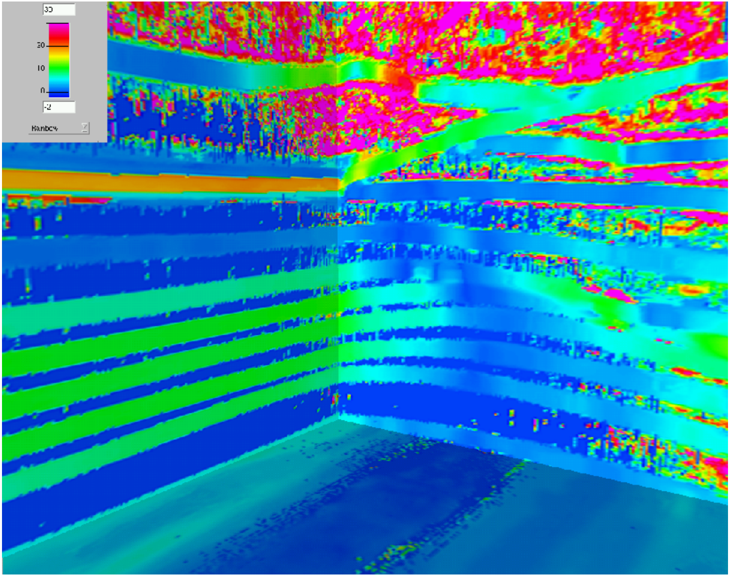

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- account for neighbouring information using windows aligned with reflection events
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- no interpretation by the user
- smoothing can improve the CRS image significantly
- automated smoothing and picking close the gap between CRS stack and NIP-wave tomography

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