Smoothing and automated picking of kinematic wavefield attributes

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- 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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- CRS attributes are subject to
  - outliers
  - non-physical fluctuations

➥ Attribute-based applications are impaired

- Application considered here:
  Tomographic determination of macro-velocity models using CRS attributes

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CRS tomography

- Advantages:
  - picking in simulated ZO volume of high S/N ratio (output of CRS)
  - pick locations independent of each other
  - very few picks required
- Quality of result depends on quality of input CRS attributes

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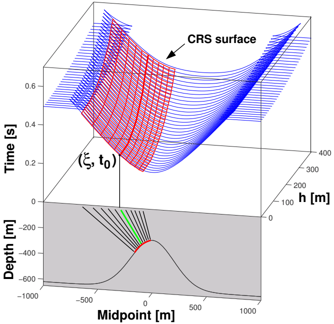
3D CRS attributes

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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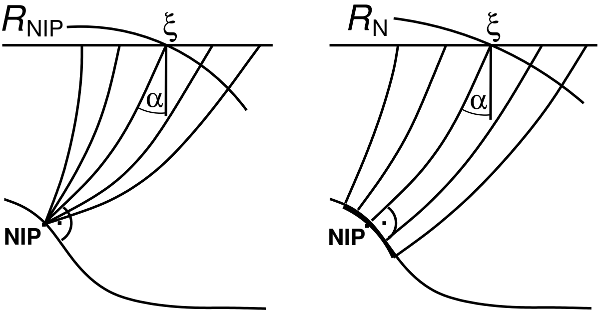

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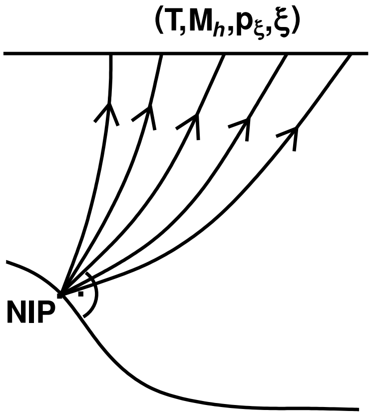
NIP waves and velocities



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

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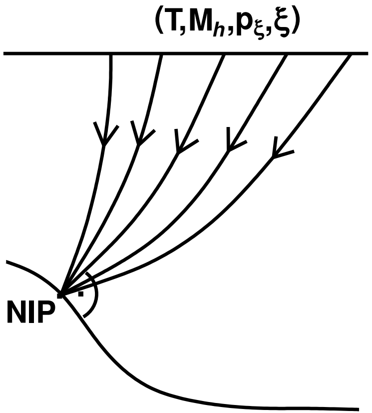
NIP waves and velocities



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

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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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Migration

- fluctuations in CRS attributes, which are not consistent with theory, influence the inversion result
- 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?
- How to do this automatically?

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- Smoothing
- optional restacking
- automated picking
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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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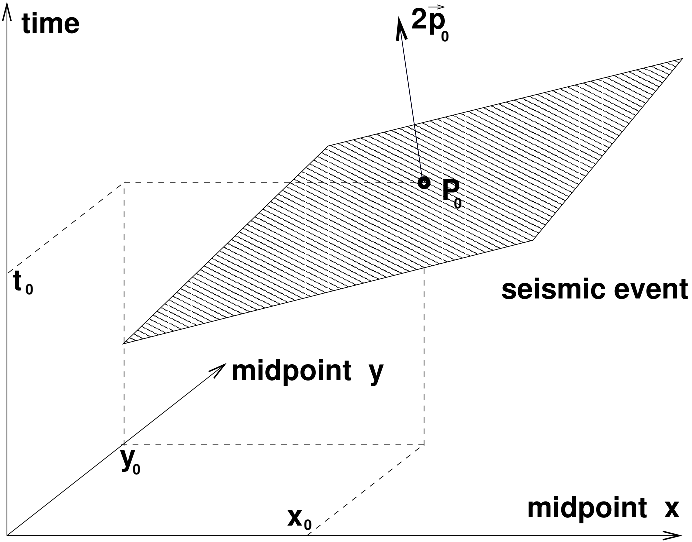
Event-aligned volume



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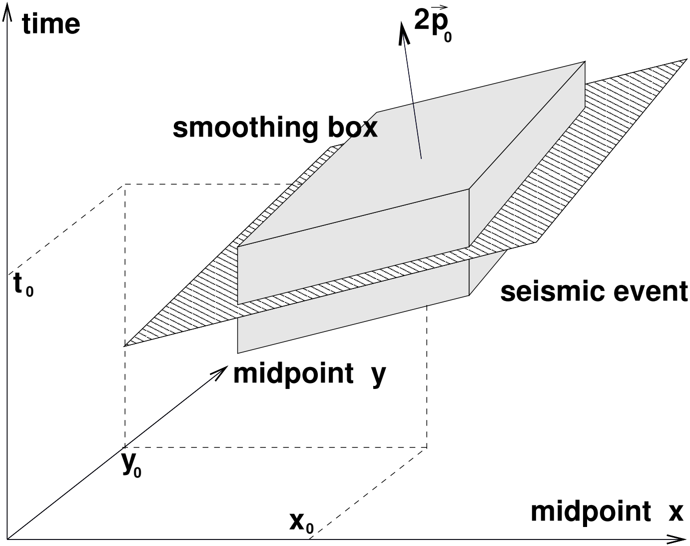

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Event-consistent smoothing

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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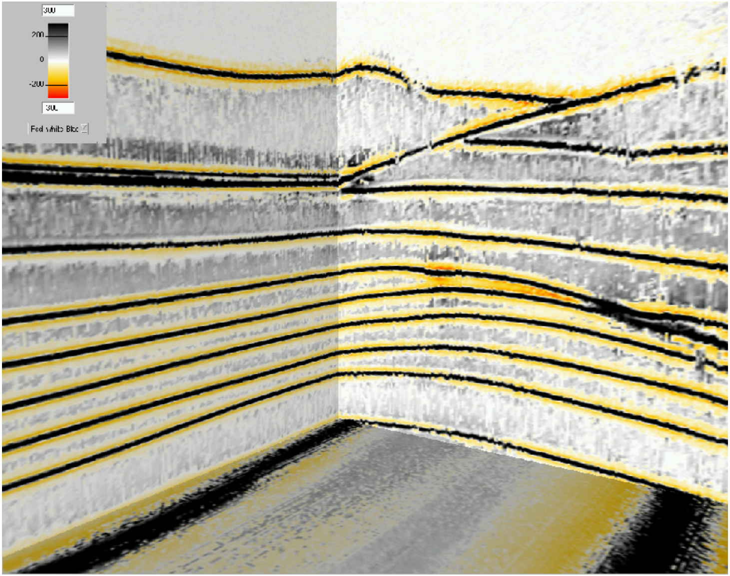
Stack, unsmoothed attributes



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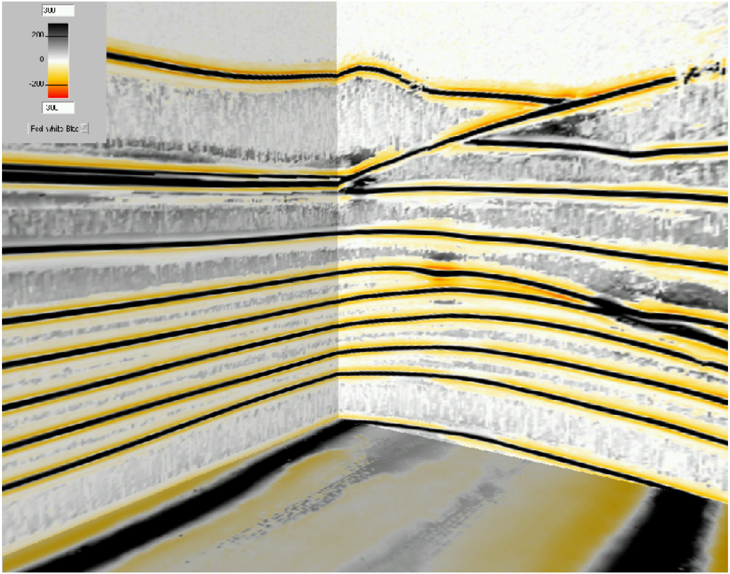
Stack, smoothed attributes



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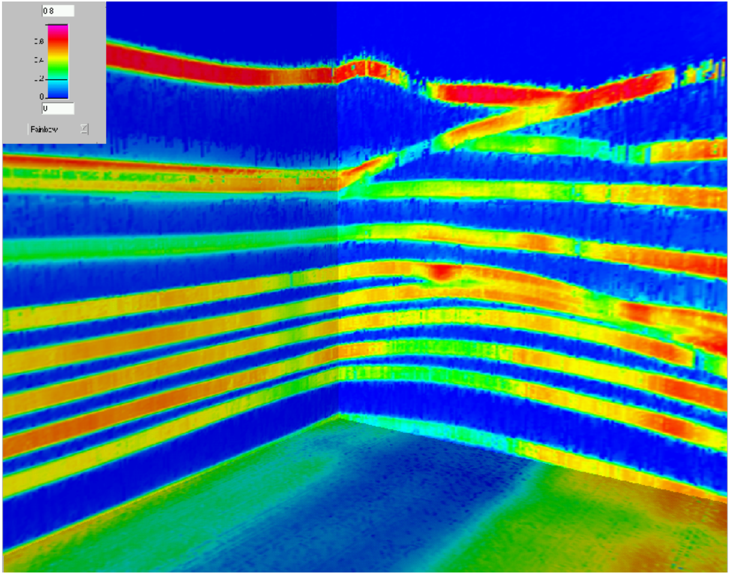

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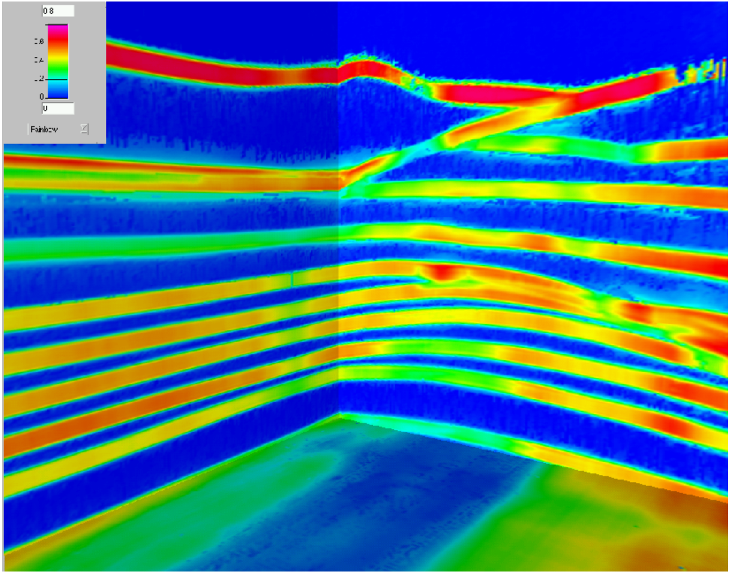

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Automated picking

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
  - has a dip difference exceeding a given threshold
- or if amplitude is below a user-defined threshold
- continue on selected trace

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  $\rightsquigarrow$ prefer high-energy events
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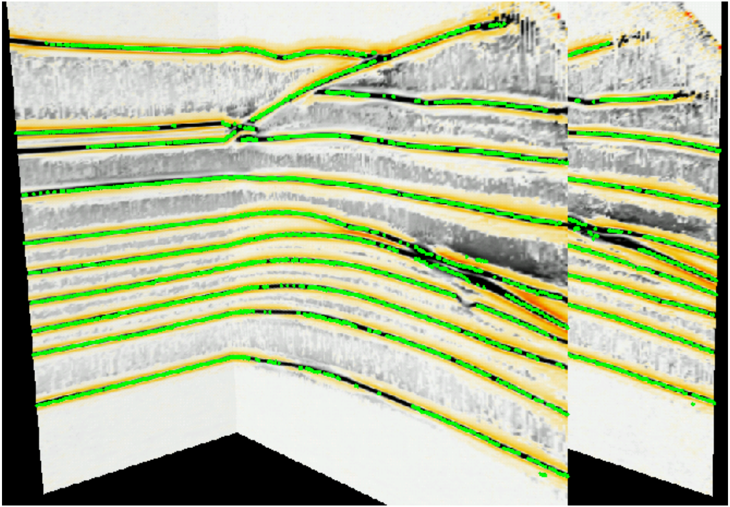

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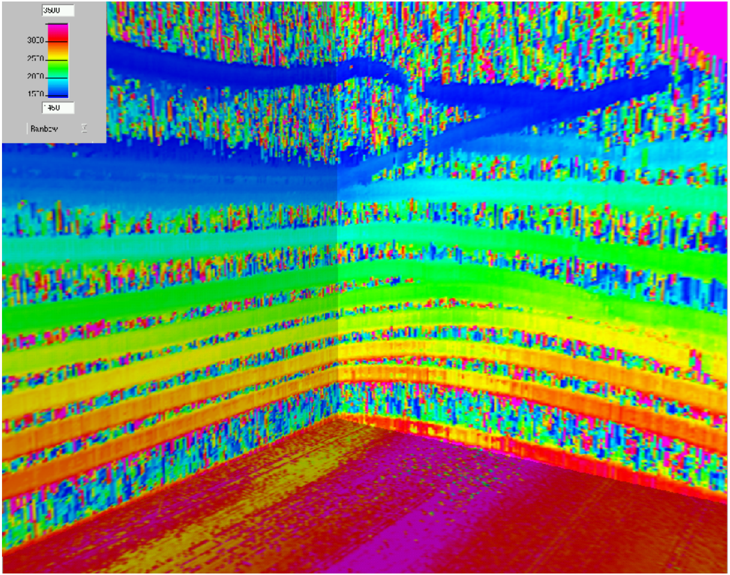
Stacking velocity



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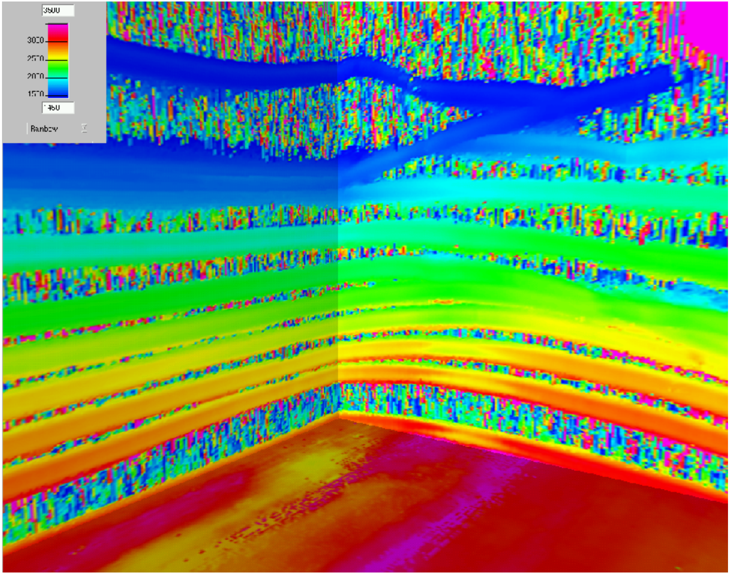
"Smoothed" stacking velocity



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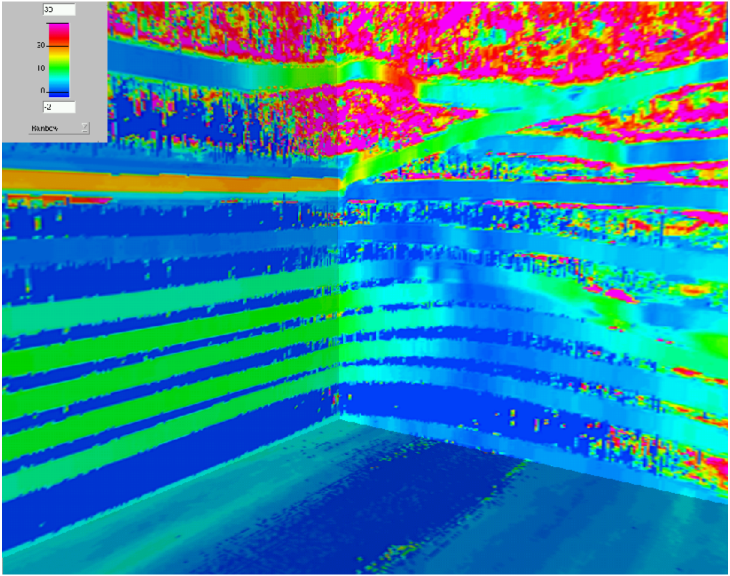

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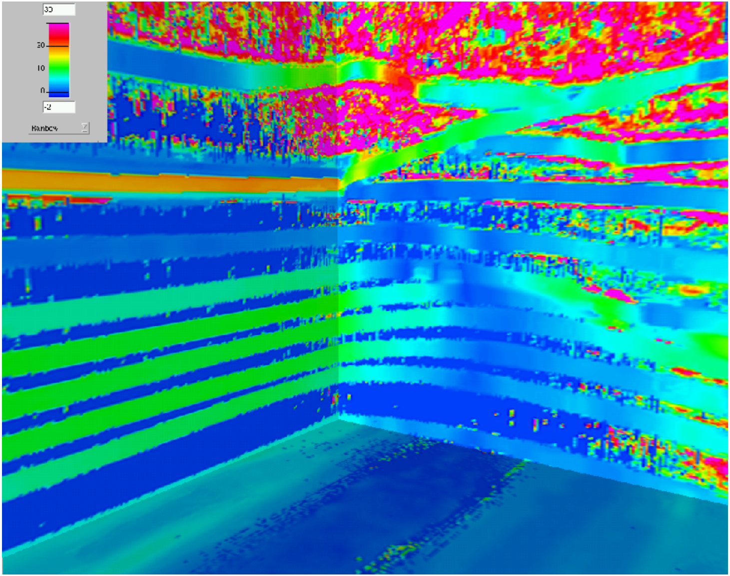

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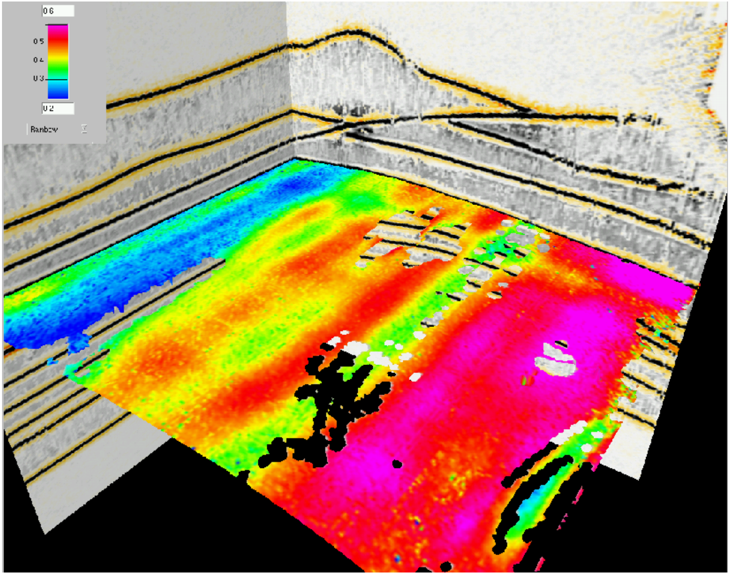
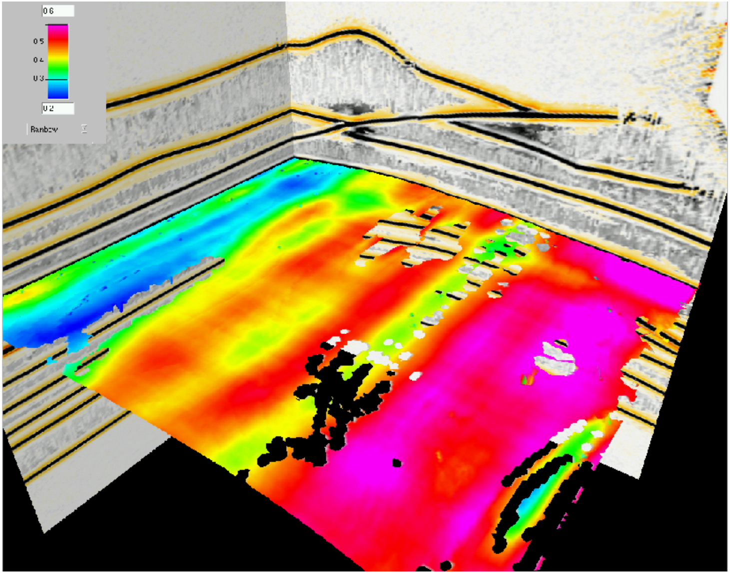


Coherence, smoothed attributes



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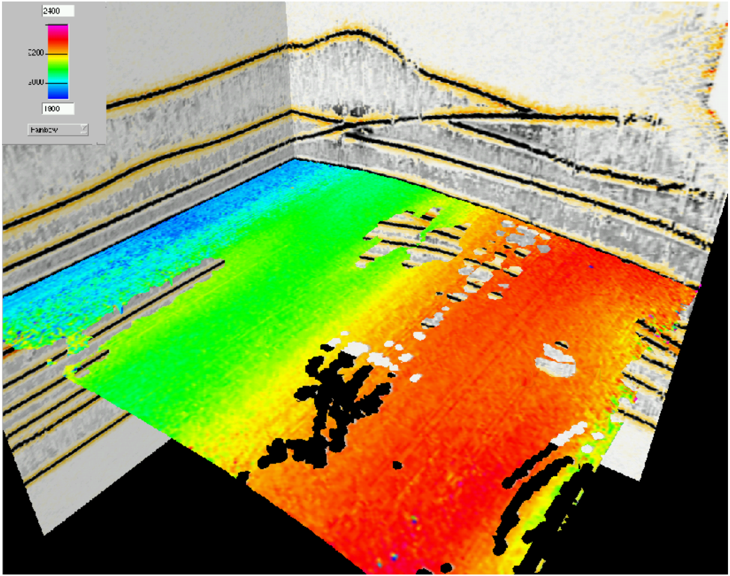

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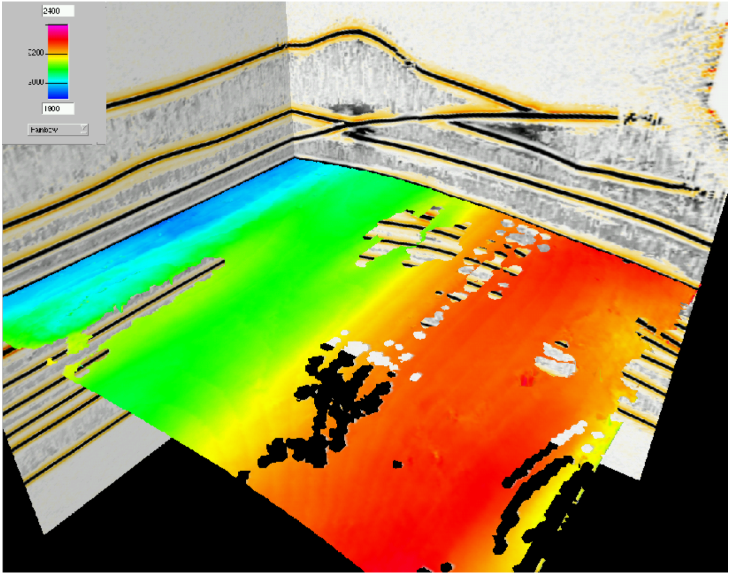
“Smoothed” stacking velocity



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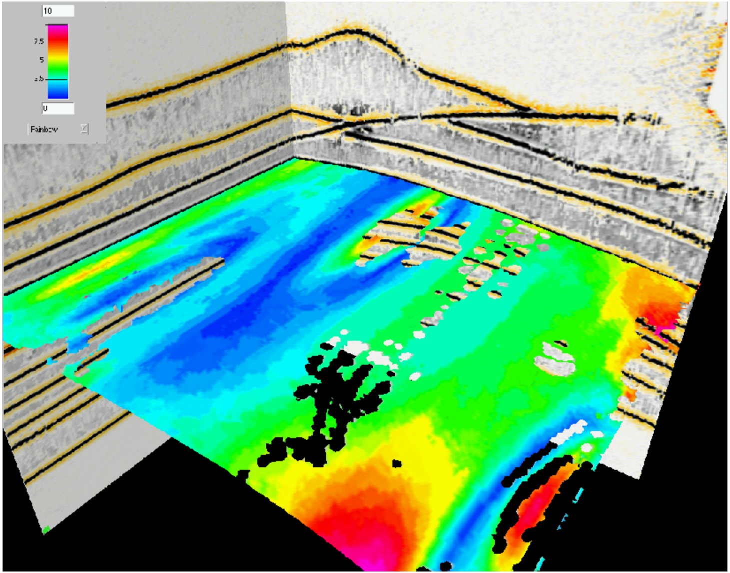

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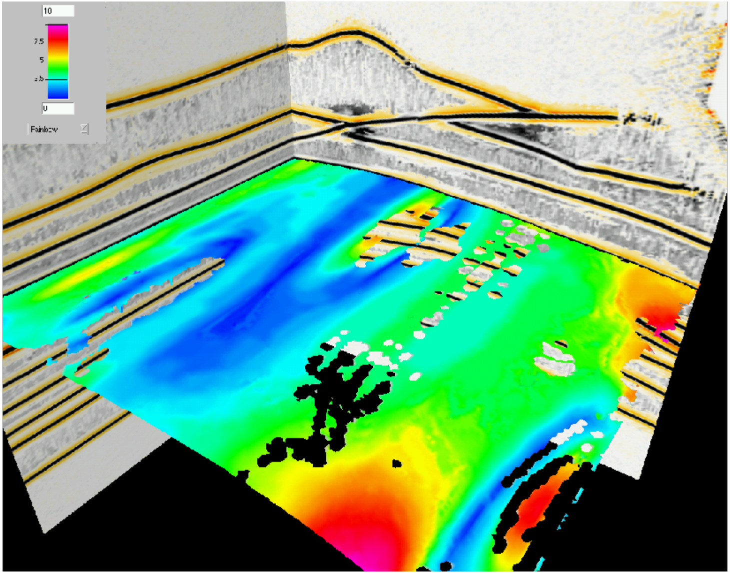

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- accounts for neighbouring information using windows aligned with reflection events
- no mixing of intersecting events
- no human interaction required
- smoothing can improve the CRS image significantly
- automated smoothing and picking closes the gap between CRS stack and NIP-wave tomography

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Workshop WS-2 “Velocity analysis for depth imaging”, Monday afternoon:

- 13:30 Common-Reflection-Surface stack – a generalized stacking velocity analysis tool

Session “Seismic Imaging”, Wednesday morning:

- 09:45 CRS-stack-based seismic imaging for land data and complex near-surface conditions
- 11:00 True-amplitude CRS-based Kirchhoff time migration for AVO analysis
- 11:25 Common-Reflection-Surface stack for OBS and VSP geometries and multi-component seismic reflection data

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