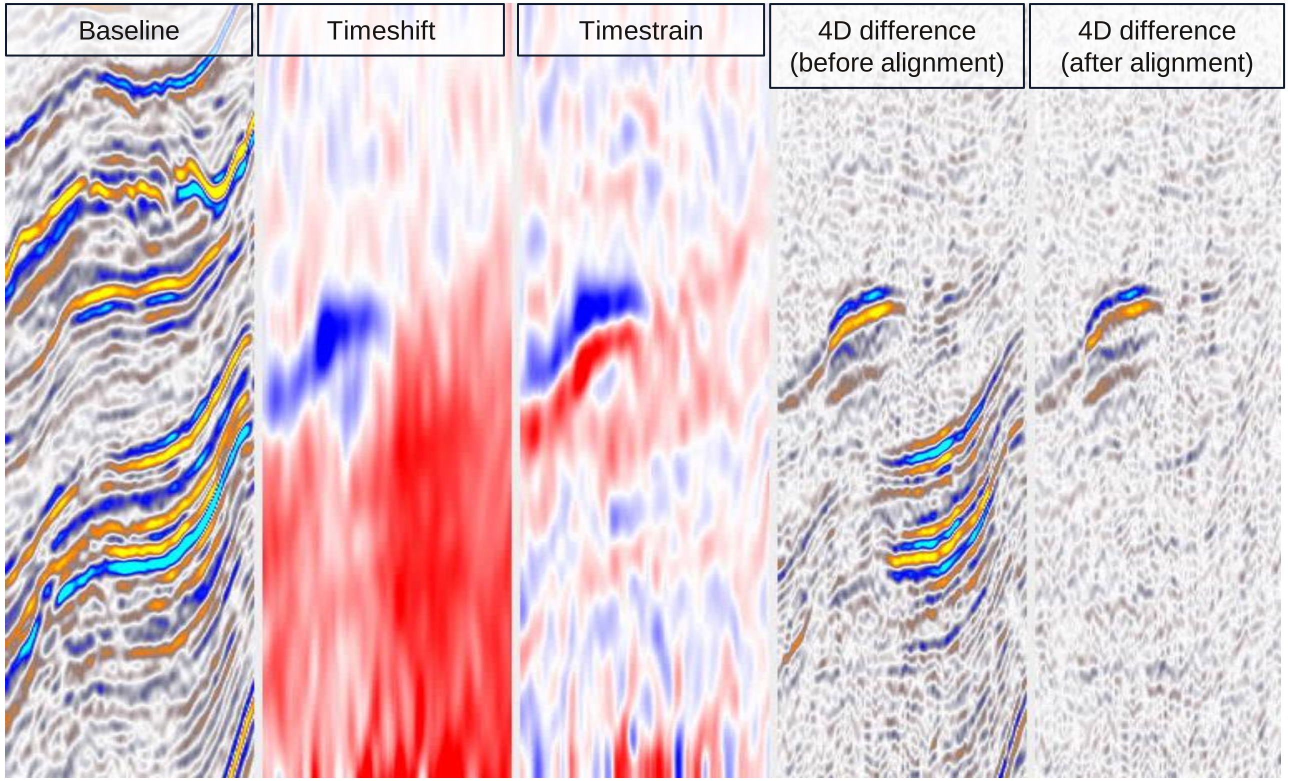
The GATHERing Knowledge Exchange

Timeshifts

Timeshift estimation, correction and interpretation



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DISCOVER MORE

21 October 2023

Timeshift estimation

This tutorial uses the project **4D_Tutorial_Leiden**

Seismic:

- Multi-vintage fullstack volume before alignment,
  - 6 vintages (1009, 1012, 1014, 1016, 1018, 1025)
- Angle-stack, Multi-vintage volume before alignment
  - 3 partial angleband stacks
  - 6 vintages
- Multi-vintage relative acoustic impedance inversion
  - 6 vintages

Horizons (map extractions):

- Top reservoir: 03_TopReservoir
- Base reservoir: 05_IntraResShale

4 Wells (for orientation only)

Fault polygons (for orientation only)

Map polygons (for surgical cross-plotting)

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Exercises: Time-lapse timeshift estimation, correction and interpretation

Learning goals

Using time-lapse timeshift estimation and correction tools

- 3 algorithms: NLI1D, timeshift.simpli and cross-correlation
- QC timeshifts and aligned volumes

- Use of timeshifts to correct for production-induced misalignment of reflectors
  - Align multi-vintage fullstack volumes
  - Align gathers using timeshifts estimated from multi-vintage fullstack volumes
- Tips and tricks and (somewhat) hidden features in the timeshift estimation tool
- Use of timestrains as a 4D attribute
  - Plotting timestrain as overlays to 3D volumes or 4D volumes
  - Map-display of reservoir timestrains
  - Comparison of maps of (i) timestrain and (ii) change in acoustic impedance between vintages

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Exercises: Time-lapse timeshift estimation, correction and interpretation

There are 6 exercises

- The first part of Exercise 1 is mandatory
- The second part of exercise 1 and all other exercises are optional, and can be done in any order (or skipped)

The last chapter (Background to timeshift estimation) is included for completeness. If you are new to time-lapse timeshifts it may be helpful to go through the slides

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Outline

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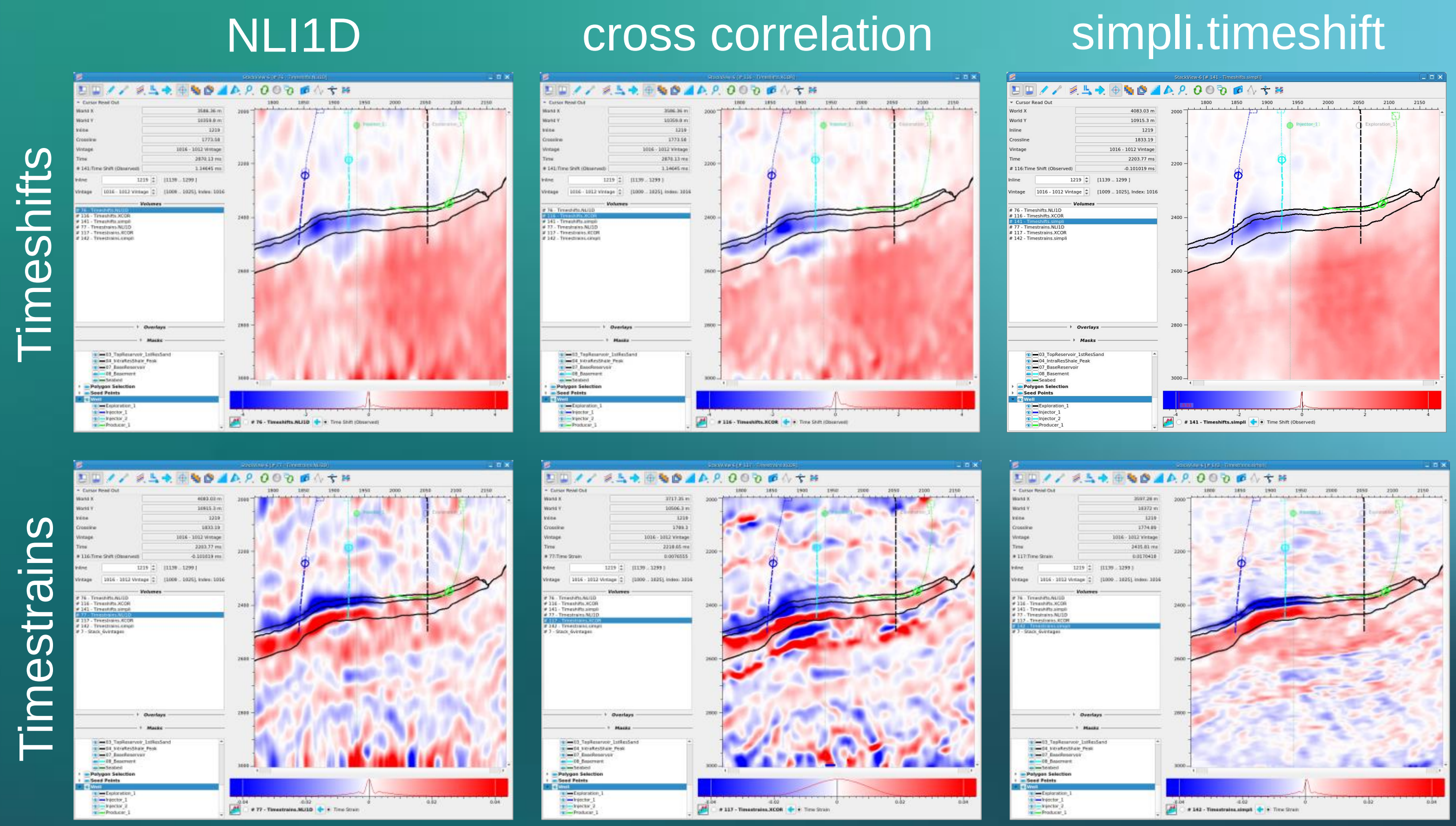
Timeshift estimation

3 algorithms:
NLI1D, cross correlation, simpli



Learning goals

- *Time alignment of base- and monitor surveys*
- *Estimated timeshifts and timestrains*

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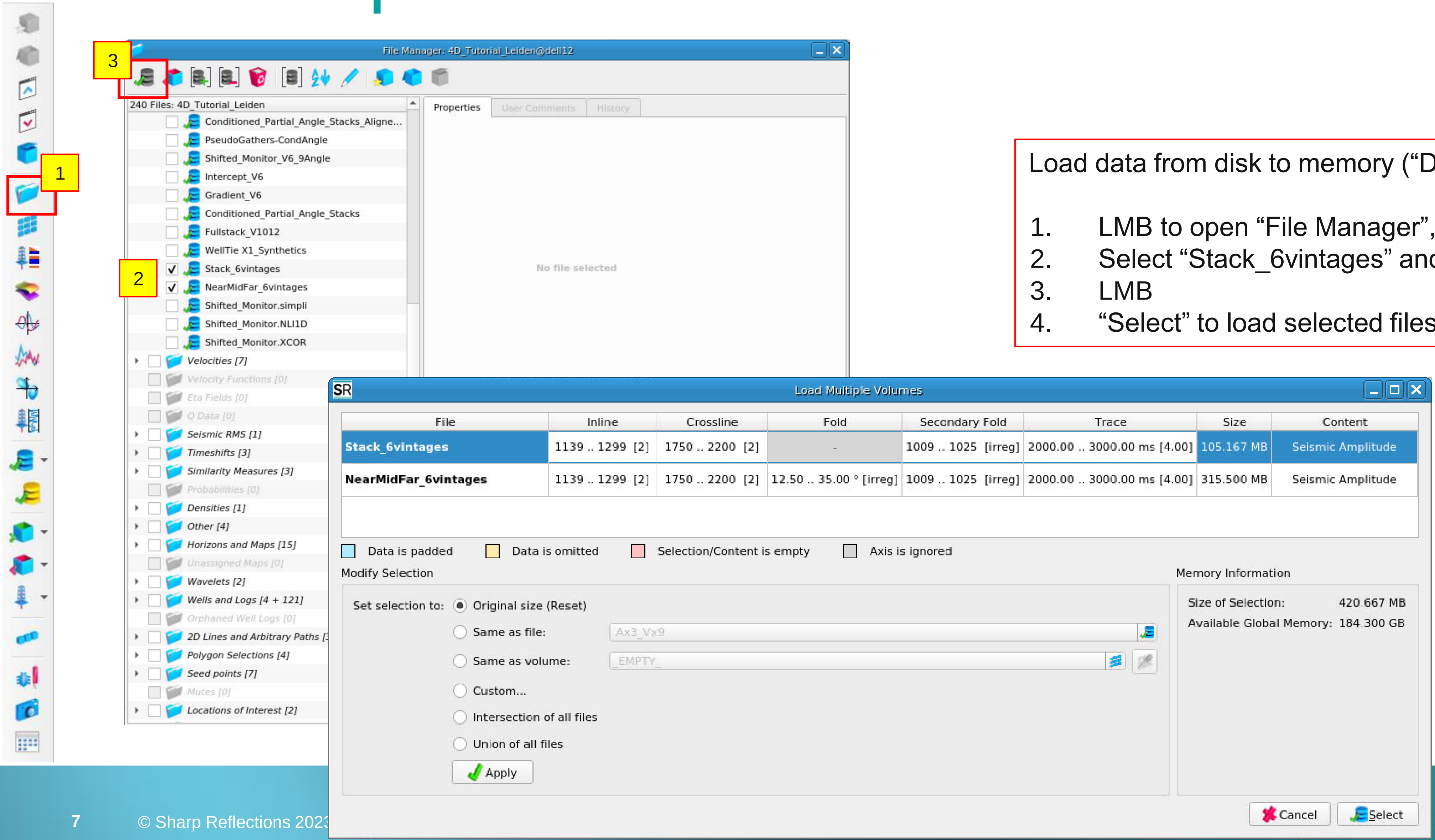
Load required data to Data Pool



Load data from disk to memory ("Data Pool")

1. LMB to open "File Manager",
2. Select "Stack_6vintages" and "NearMidFar_6vintages"
3. LMB
4. "Select" to load selected files to memory ("Data Pool")

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Exercise 1

Three timeshift estimation algorithms: NLI1D, cross–correlation and simpli

Task:

Run all three algorithm to create

- Time-lapse timeshift volumes
- Timeshift corrected multi-vintage seismic volumes
- Timestrain volumes

Note:
You are not required to use all three algorithms, and you can skip 2 out of 3 runs.
All three algorithms are shown to see the algorithm parameters, and to demonstrate that similar quality of time aligned seismic is achieved.

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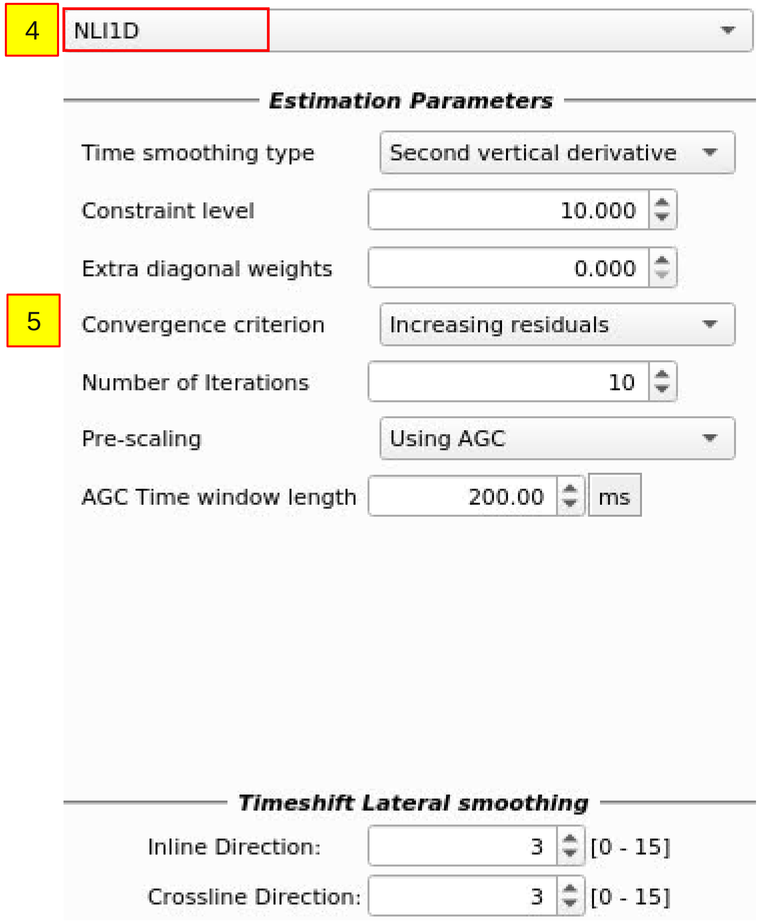
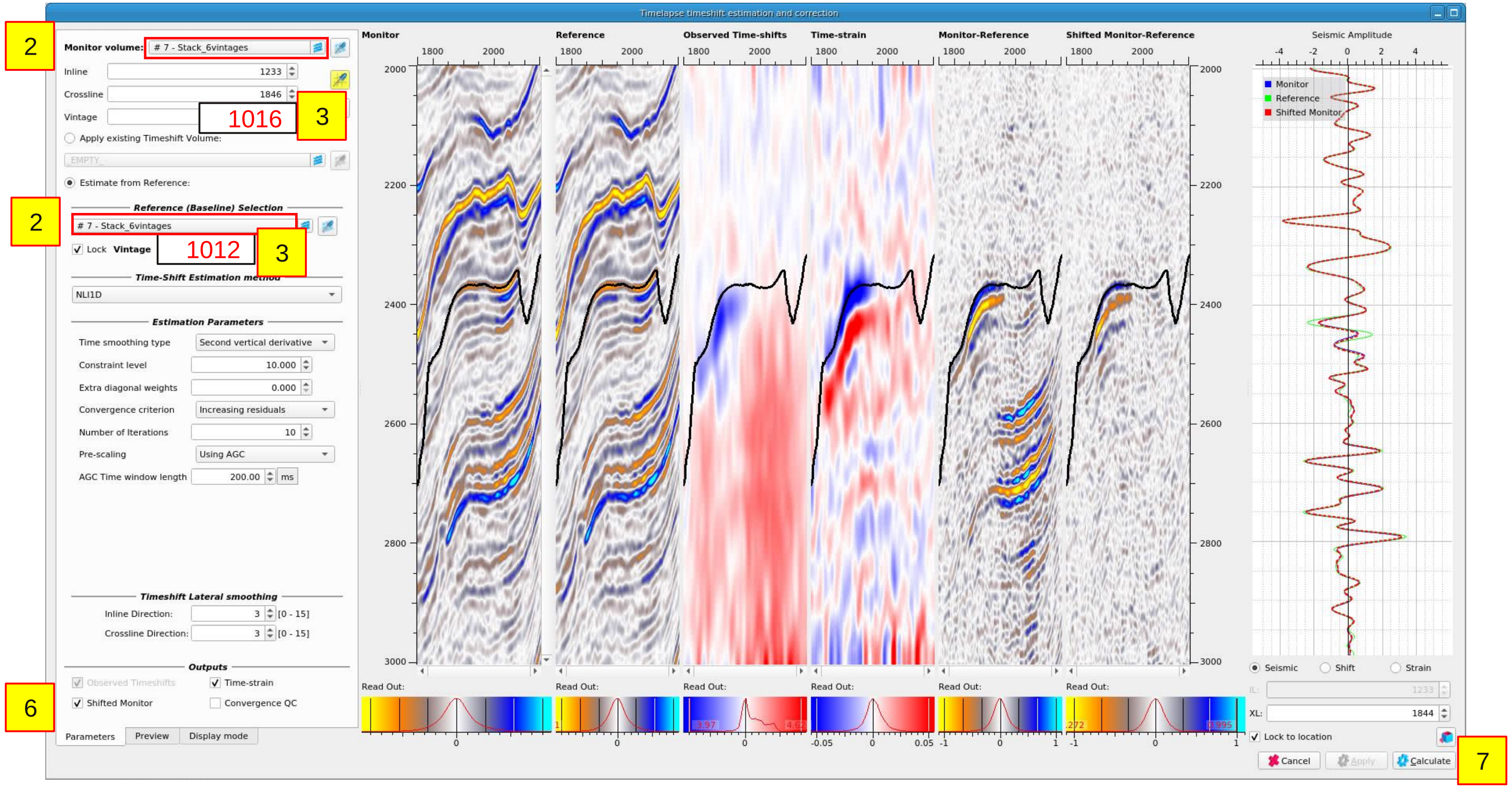
Timeshifts: NLI1D



Exercise 1

Execute timeshift estimation using three different algorithms

1. "Processing" → "Time-shift Estimate".
2. Use "Stack_6vintages" for both *Monitor* and *Reference* volume
3. Vintage selection for *Monitor* and *Reference* volume, respectively
4. Algorithm selection: *NLI1D*
5. Parameter selection for specified algorithm (Test "Constraint Level" using [0.1, 1.0, 10.0, and 100.0] and observe, also test using options for "Time smoothing type")
6. Output selection. Select "Shifted Monitor" and "Timestrain"
7. *Calculate* to run algorithm on full volumes



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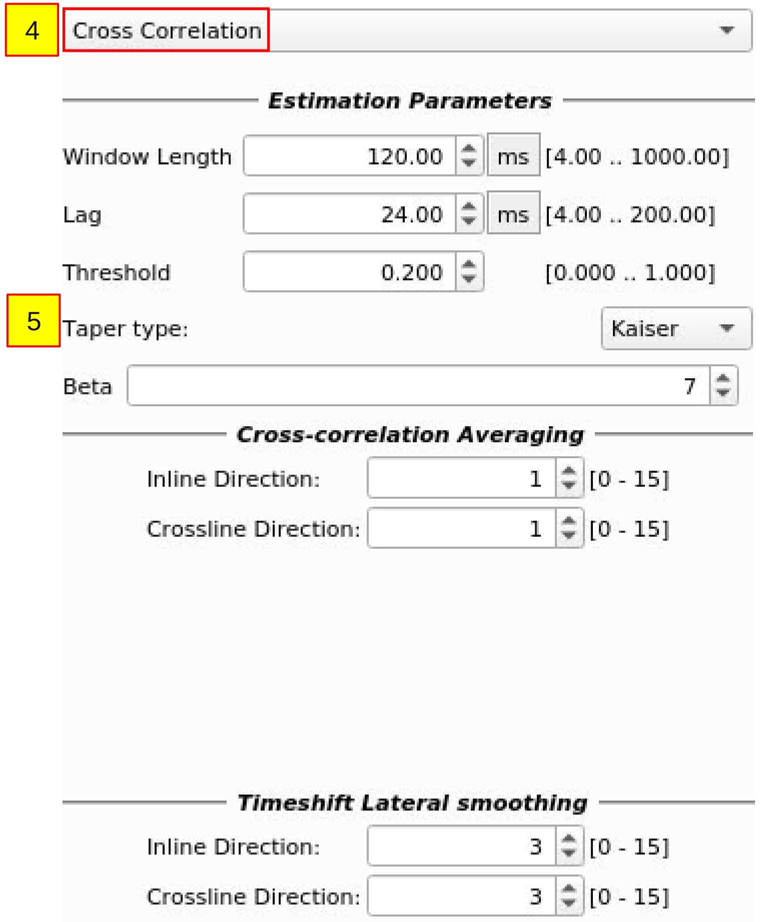
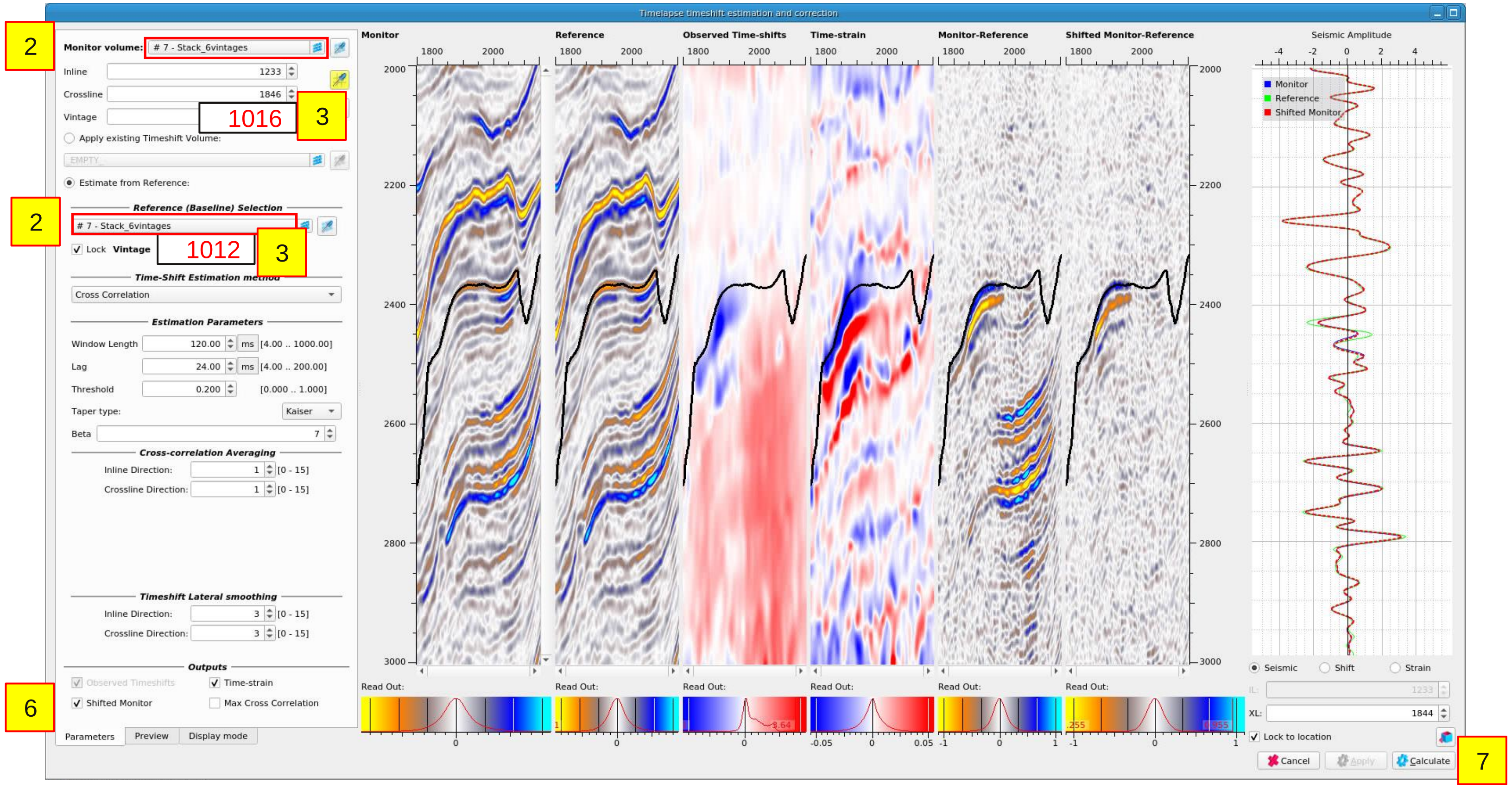
Timeshifts: Cross-correlation

Execute timeshift estimation using three different algorithms

1. "Processing" → "Time-shift Estimate". Or in data pool, RMB on output from previous run "Edit copy …"
2. Use "Stack_6vintages" for both *Monitor* and *Reference* volume
3. Vintage selection for *Monitor* and *Reference* volume, respectively
4. Algorithm selection: *Cross correlation*
5. Parameter selection for specified algorithm. Again play with algorithm parameters and think whether you can see expected behaviour in preview. Discuss with whoever is close-by
6. Output selection. Select "Shifted Monitor" and "Timestrain"
7. *Calculate* to run algorithm on full volumes





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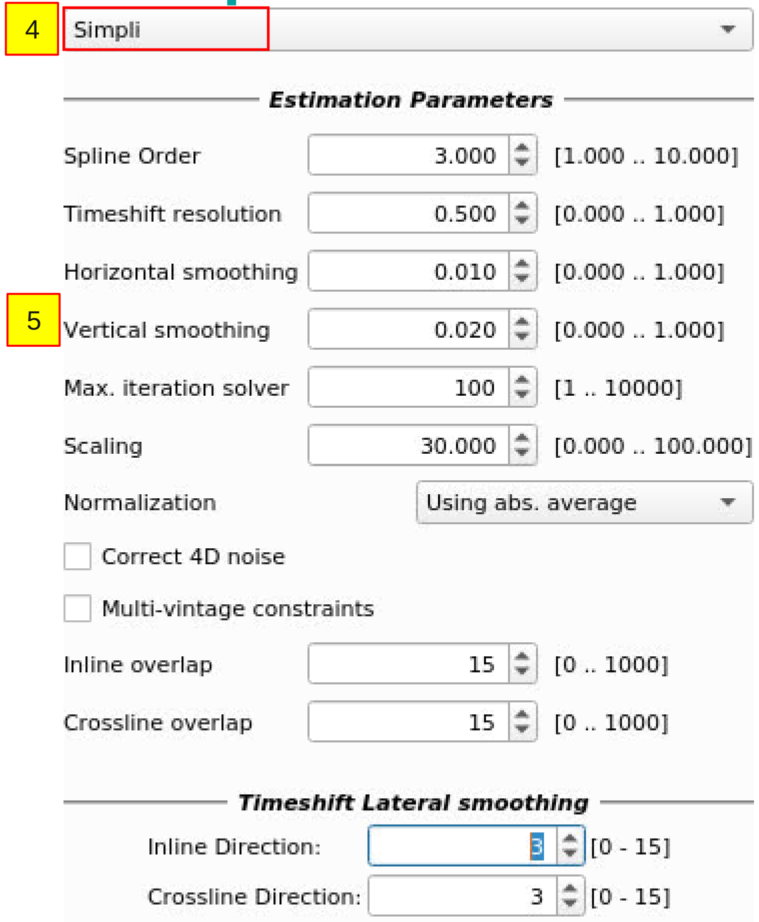
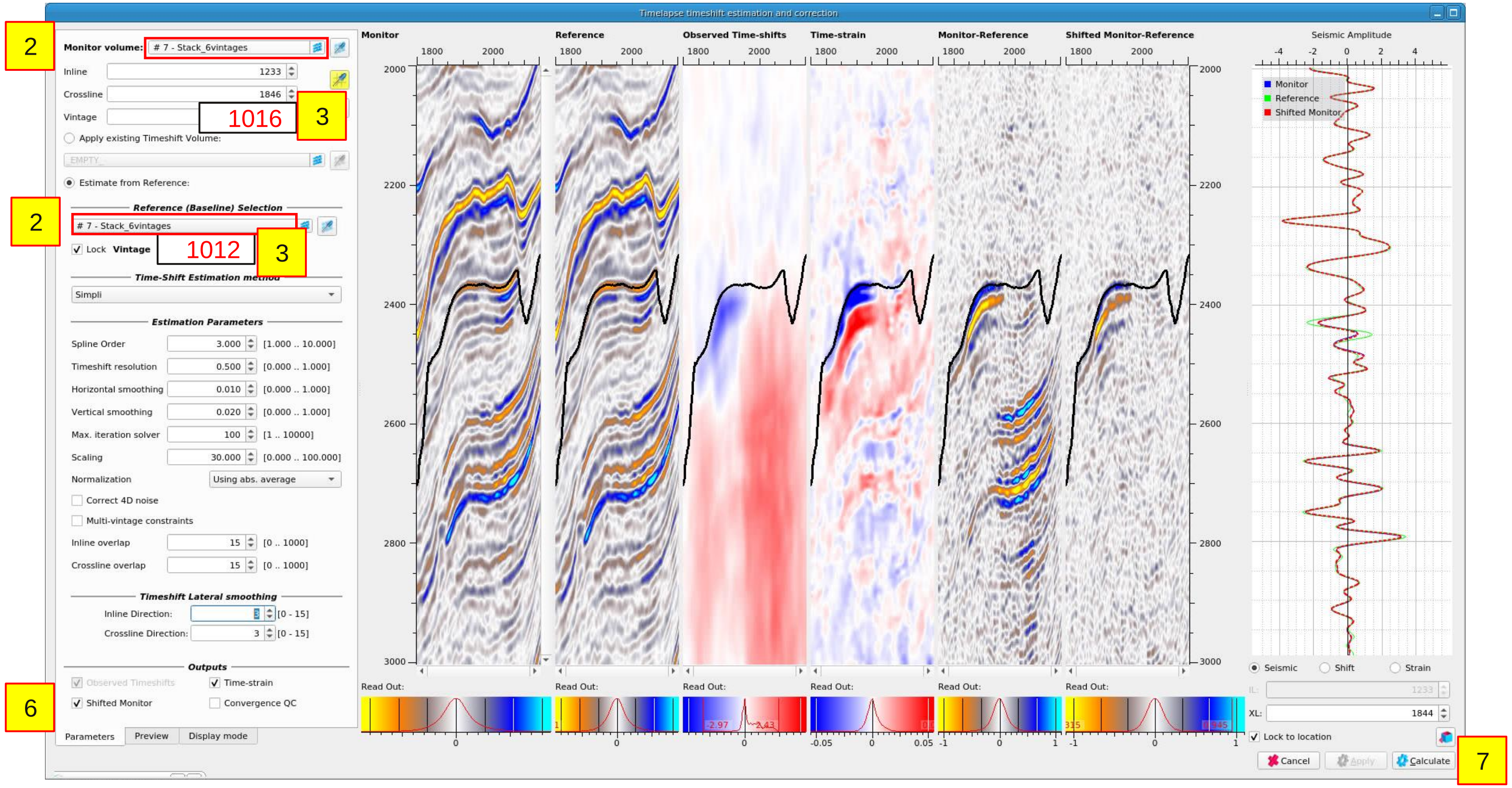
Timeshifts: simpli



Execute timeshift estimation using three different algorithms

1. "Processing" → "Time-shift Estimate". Or in data pool, RMB on output from previous run "Edit copy …"
2. Use "Stack_6vintages" for both *Monitor* and *Reference* volume
3. Vintage selection for *Monitor* and *Reference* volume, respectively
4. Algorithm selection: *Simpli*
5. Parameter selection for specified algorithm. If you set "Spline Order" to 1 (Default=3 is good), it is easiest to see how the algorithm works. Results will be suboptimal. Ask if you are interested.
6. Output selection. Select "Shifted Monitor" and "Timestrain"
7. *Calculate* to run algorithm on full volumes



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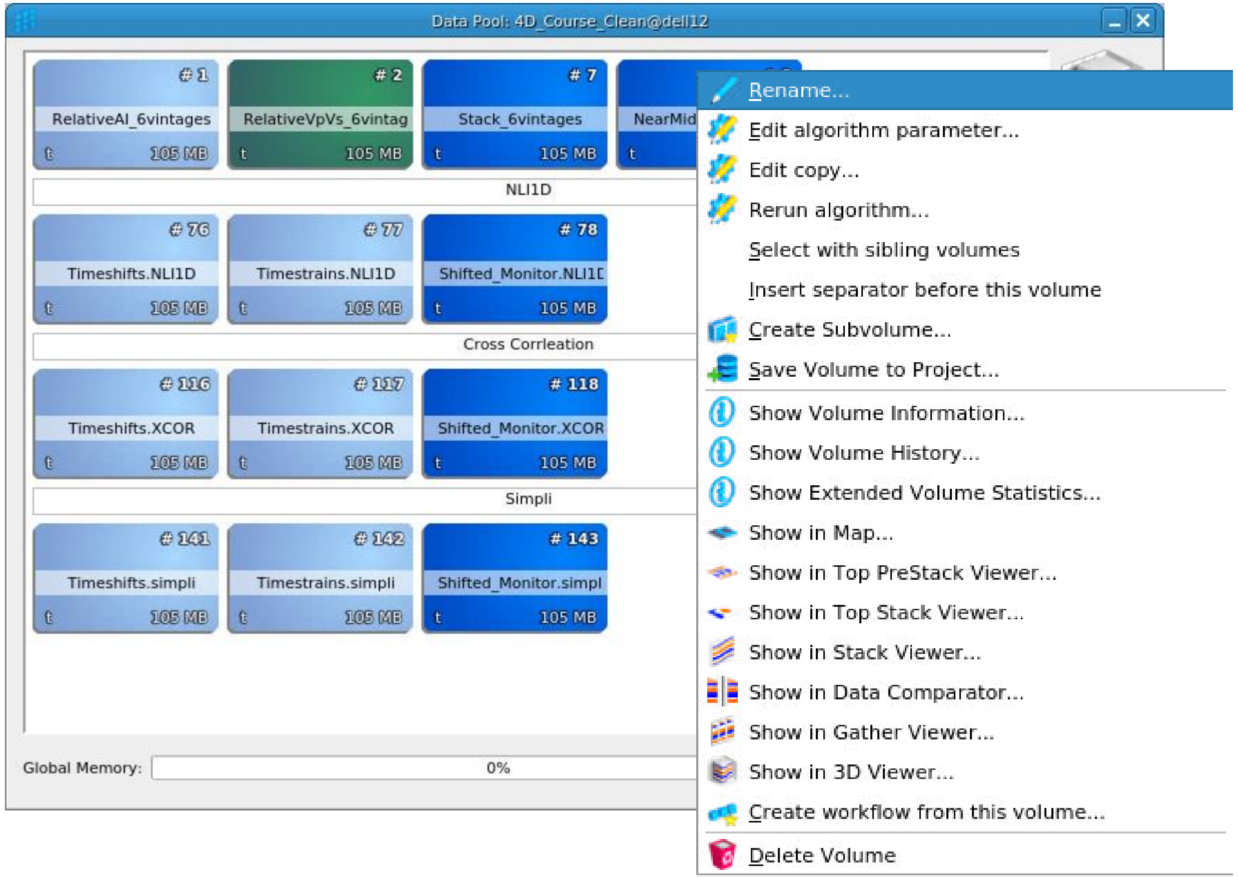
Organize data pool after timeshift calculations



Note:
You can skip this step.
All data are saved to project, and can be loaded from using file-manager

Organize datapool

1. RMB on a tile, “Rename” to choose a new name
2. RMB on a tile, “Insert separator before this volume” to insert separator
3. RMB on separator allows assigning a name to separator

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Three timeshift estimation algorithms: NLI1D, cross–correlation and simpli

Task:
Investigate the differences in time-aligned monitor volumes and estimated timeshifts/timestrains using the three algorithms

Observations you will make:

- The differences in estimated timeshifts and timestrains using three different algorithms can locally be quite large (in terms of percentage differences), yet the time-aligned seismic volumes are quite similar

Question:

- What does this tell you about how to interpret timeshifts and timestrains?
- Will this affect how you
  - Estimate timeshifts for alignment of base- and monitor surveys?
  - Estimate timeshifts and timestrains for use as time-lapse attributes?

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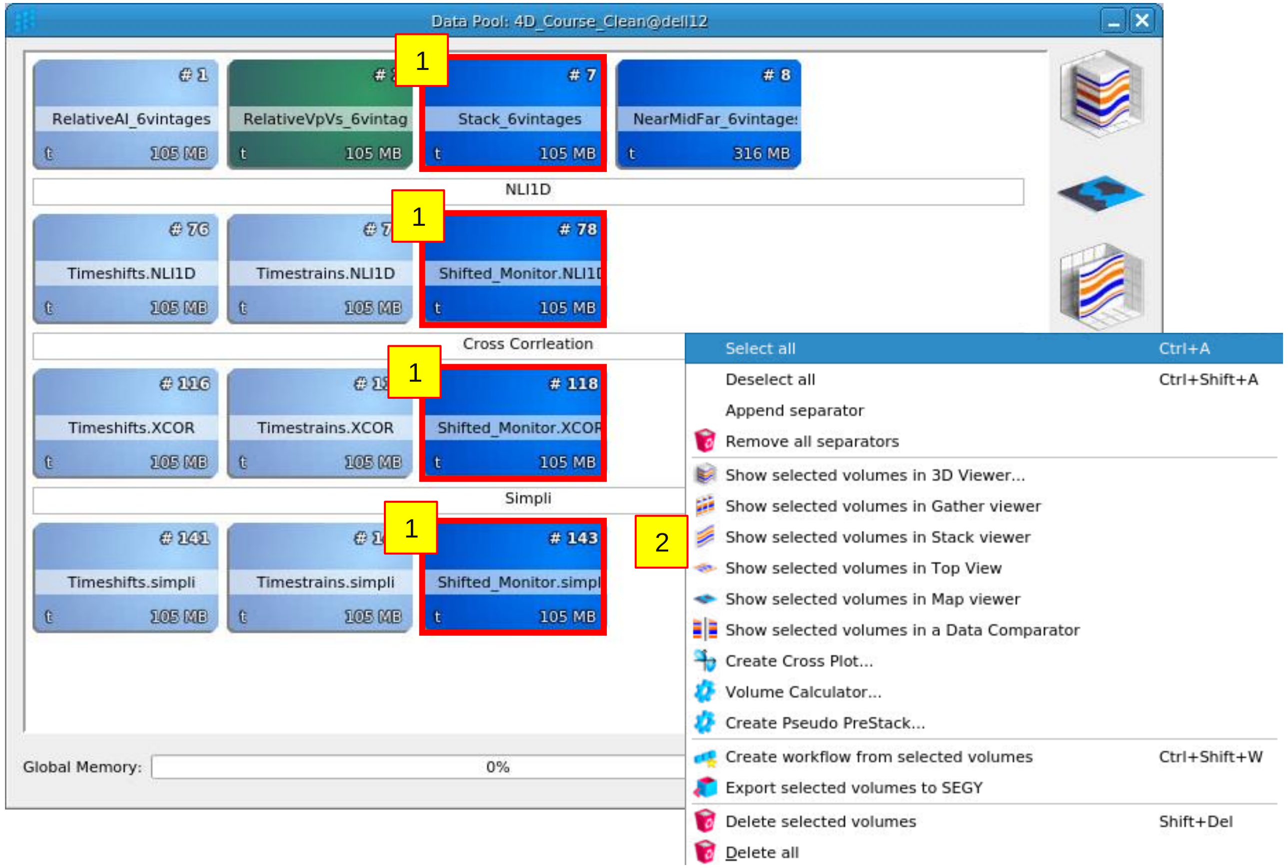
Comparison of timeshift-corrected seismic and estimated timeshifts from three estimation methods



Using "difference-in-viewer" in "Stack Viewer", compare the outputs from three different methods of timeshift estimation and correction.

For ease of finding data, I have renamed the volumes (RMB on data in data-pool, and "Rename"), and I have inserted separators (RMB on data in data-pool, and "Insert separator before this volume")

1. Select data volume by Ctrl+LMB
   - Multi-vintage fullstack seismic before correction ("Stack_6vintages") and
   - Aligned multi-vintage seismic ("Shifted_Monitor.NLI1D", "Shifted_Monitor.XCOR", and "Shifted_Monitor.simpli")
2. Display multiple data volumes by RMB in empty space in data pool and "Show selected volumes in Stack Viewer

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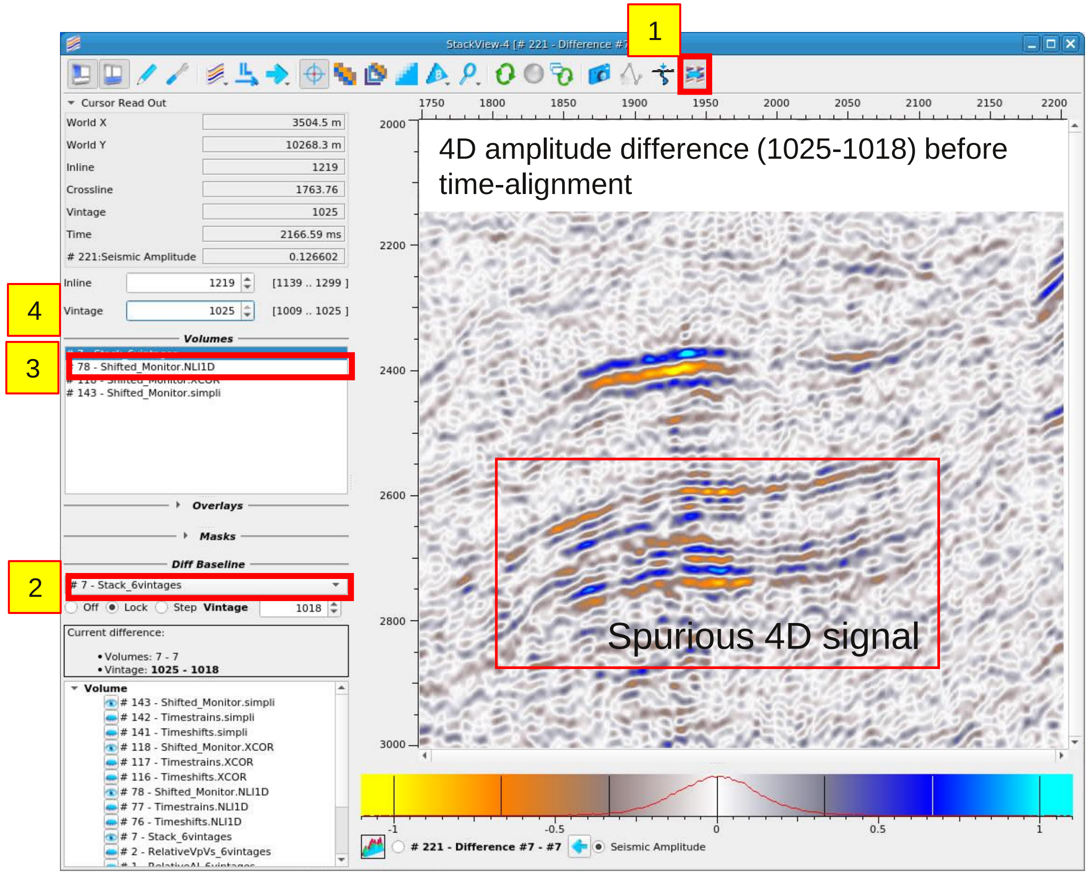
4D Amplitude differences before time-alignment



Using “difference-in-viewer” in “Stack Viewer”, compare the 4D differences before and after alignment (3 methods)

1. Enable “Difference in Viewer”
2. Choose ”Stack_6vintages” as baseline. Tick the vintage control to “Lock” and set Vinatge 01018
3. Choose ”Stack_6vintages” as monitor Volume.
4. Scan different monitor vintages

Note that for most vintage differences there are large amplitude differences in the underburden between the seismic volume before alignment and after alignment

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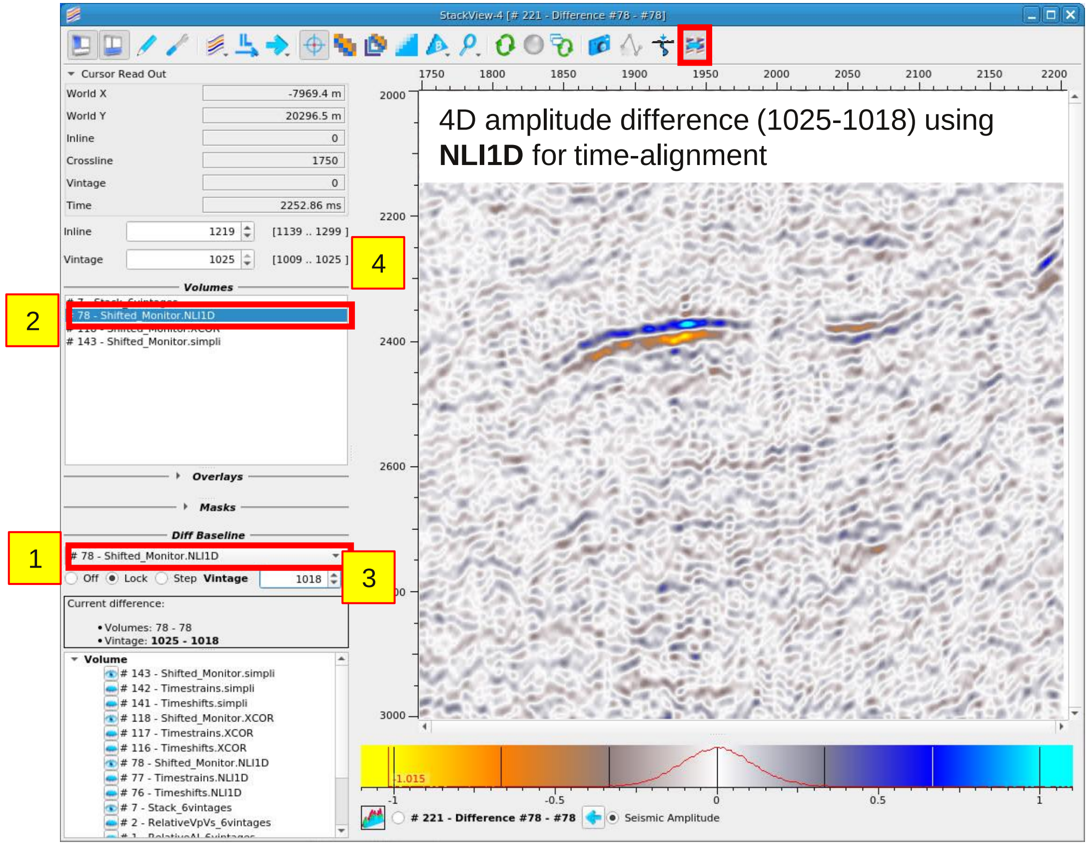
4D Amplitude differences in aligned data *NLI1D*



Using "difference-in-viewer" in "Stack Viewer", compare the time-aligned 4D difference from three different methods of timeshift estimation and correction

1. Now choose time-aligned data (e.g., "Shifted_Monitor.NLI1D") as a baseline
2. Choose the same volume as a monitor
3. Set a reference vintage via "Lock" for the vintage control. This allows to select a baseline vintage via the Vintage selector (here 1018). ("Step" enables sequential vintage selection)
4. Set a monitor vintage (here 1025)

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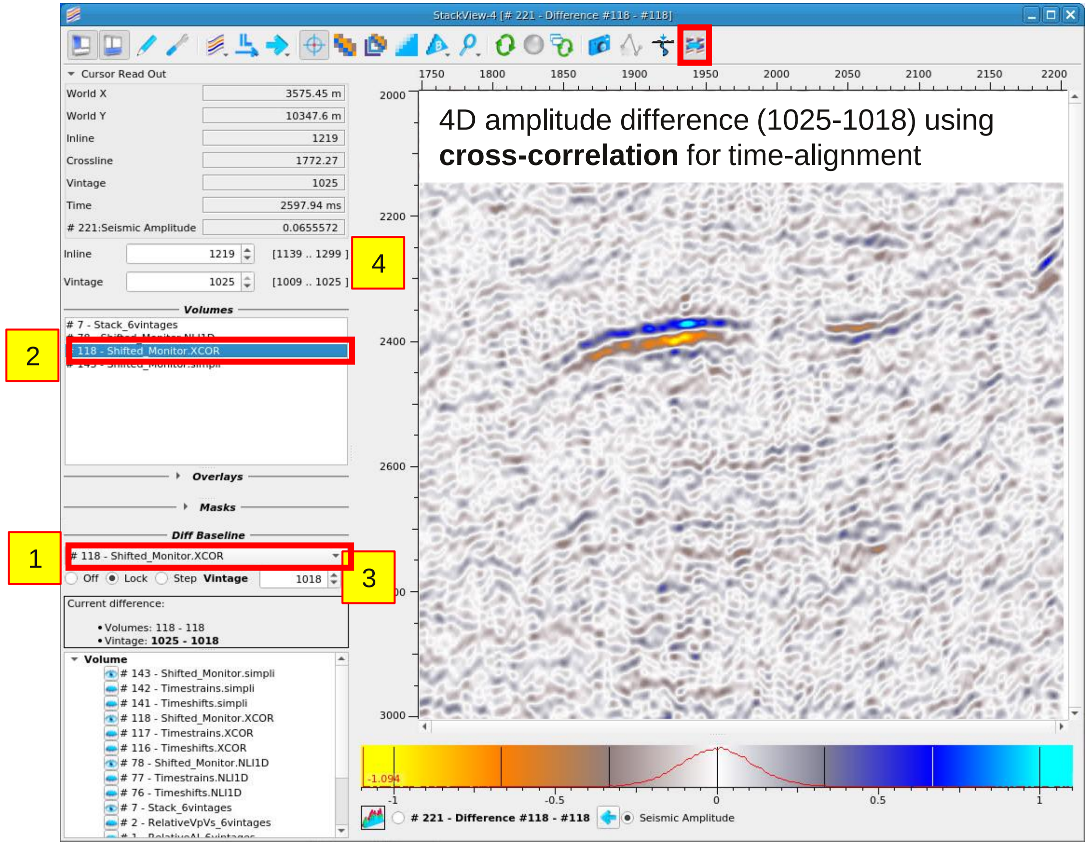
Amplitude differences in aligned data
Cross-correlation



Using “difference-in-viewer” in “Stack Viewer”, compare the time-aligned 4D difference from three different methods of timeshift estimation and correction

1. Now choose time-aligned data (e.g., ”Shifted_Monitor.XCOR”) as a baseline
2. Choose the same volume as a monitor
3. Set a reference vintage via “Lock” and Vintage scrollbar (here 1018)
4. Set a monitor vintage (here 1025)

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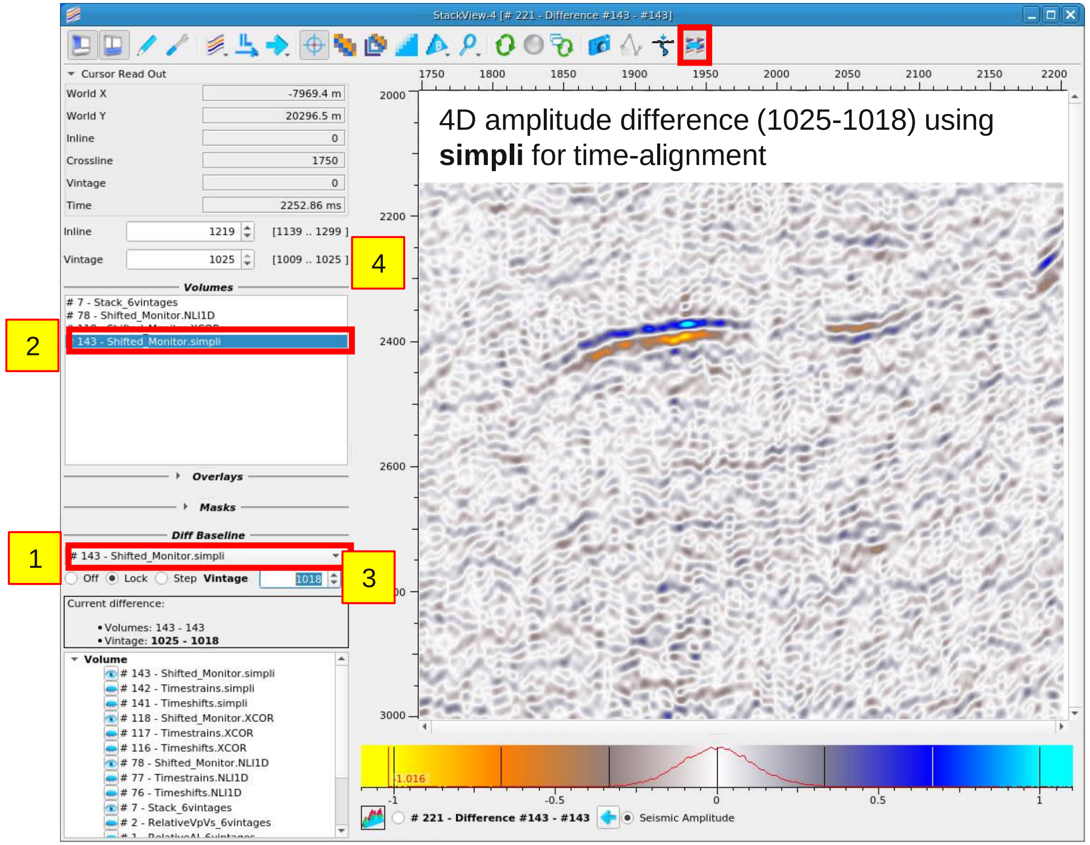
Amplitude differences in aligned data *simpli*



Using "difference-in-viewer" in "Stack Viewer", compare the time-aligned 4D difference from three different methods of timeshift estimation and correction

1. Now choose time-aligned data (e.g., "Shifted_Monitor.simpli") as a baseline
2. Choose the same volume as a monitor
3. Set a reference vintage via "Lock" and Vintage scrollbar (here 1018)
4. Set a monitor vintage (here 1025)

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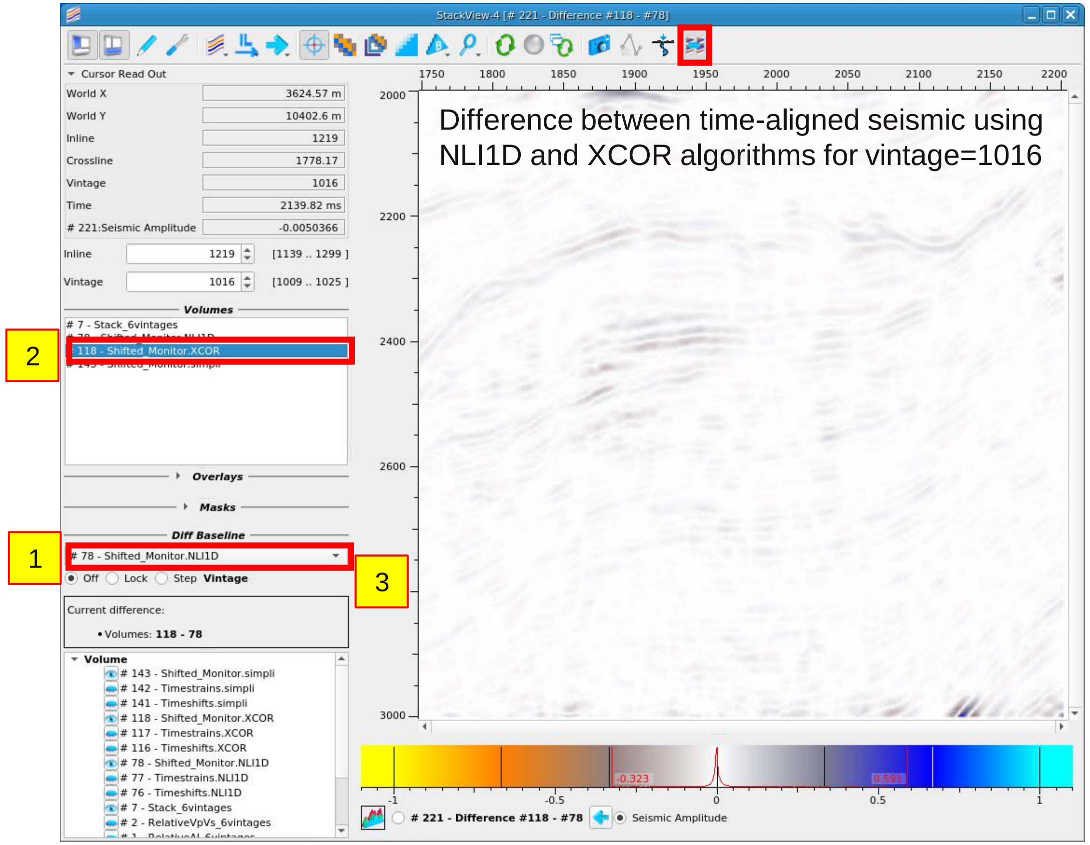
Comparison of timeshift-corrected seismic and estimated timeshifts from three estimation methods



Using “difference-in-viewer” in “Stack Viewer”, compare the outputs from three different methods of timeshift estimation and correction

1. Now choose any of the three time-aligned volumes as a baseline, e.g., ” Shifted_Monitor.NLI1D”
2. Choose any of the other two shifted time-shifted volumes
   - “Shifted_Monitor.XCOR”, and
   - “Shifted_Monitor.simpli”)

   as monitor Volume.
3. Set the “Diff Baseline” Vintage to “None” using the radio button. This causes the Vintage control of the primary Volume (Monitor) to act on both Baseline and Monitor

Note the marginal differences between the various combinations of time-aligned volumes. This shows that all three algorithms result in similar data after alignment

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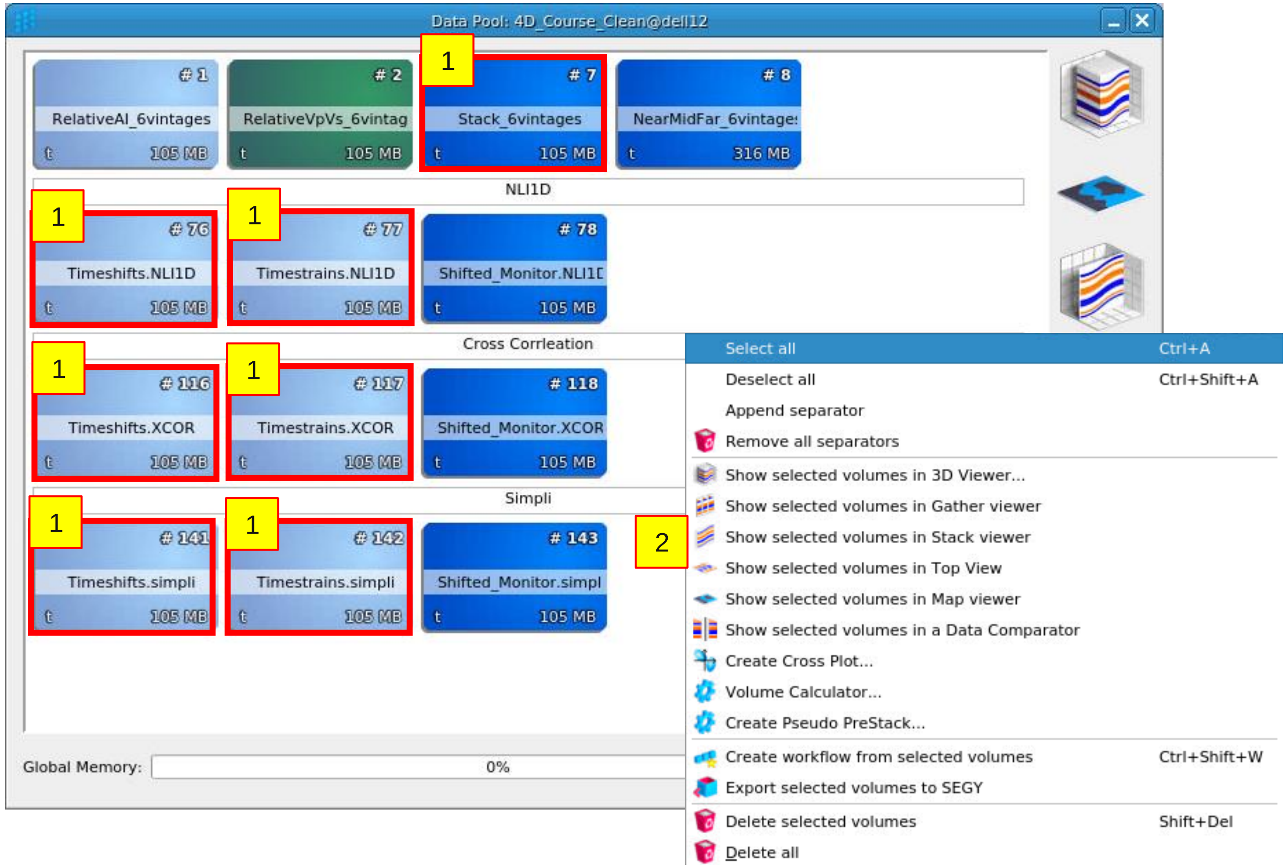
Estimated timelapse timeshifts



Using “difference-in-viewer” in “Stack Viewer”, compare the outputs from three different methods of timeshift estimation and correction.

1. Select data volume by Ctrl+LMB
   - Multi-vintage fullstack seismic before correction (“Stack_6vintages”) and
   - Timeshift volumes (“Timeshifts.NLI1D”, “Timeshifts.XCOR”, and “Timeshifts.simpli”)
   - Timestrain volumes (“Timestrains.NLI1D”, “Timestrains.XCOR”, and “Timestrains.simpli”)

2. Display multiple data volumes by RMB in empty space in data pool and “Show selected volumes in Stack Viewer

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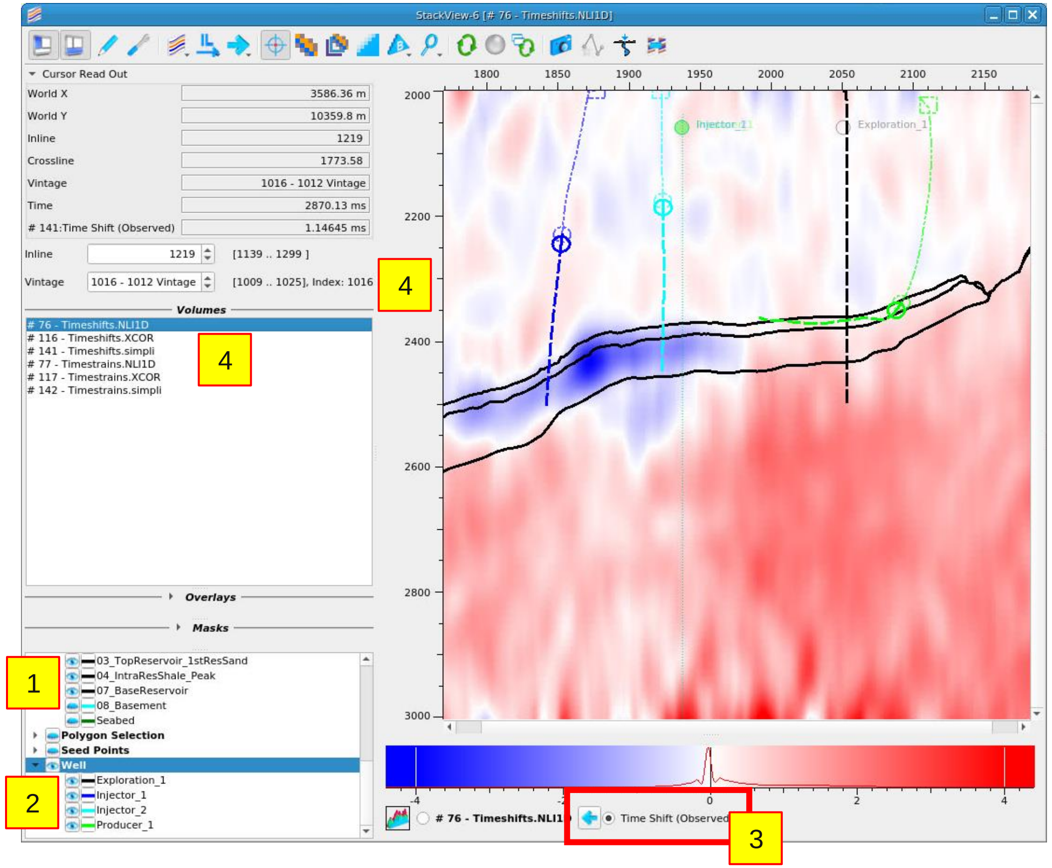
Estimated timelapse timeshifts



Compare estimated timeshifts and timestrains from different methods. Questions to think about:

- Are the amplitudes using the 3 methods comparable?
- Which method predicts the largest timeshifts (and why)?
- Are there different characteristics in the predicted timeshifts/timestrains between the three methods?
- How would you adjust parameters to change the characteristics (short wavelength vs. long wavelength features in the timeshift fields)?

1. Display wells
2. Display horizons
   - Top reservoir = “03_TopReservoir_1stResSand”
   - Base producing layer = “04_IntraResShale_Peak”
   - Base second (water) sand = “07_BaseReservoir”
3. Adjust colourbars
   - Timeshifts (e.g., [-4 4] ms).
     - “Content specific histogram” (right radio button) → scaling for all volumes of the same data-type
     - “Volume specific histogram” (left radio button) → scaling for displayed volume only
4. Cycle through the various volumes and various vintages and observe

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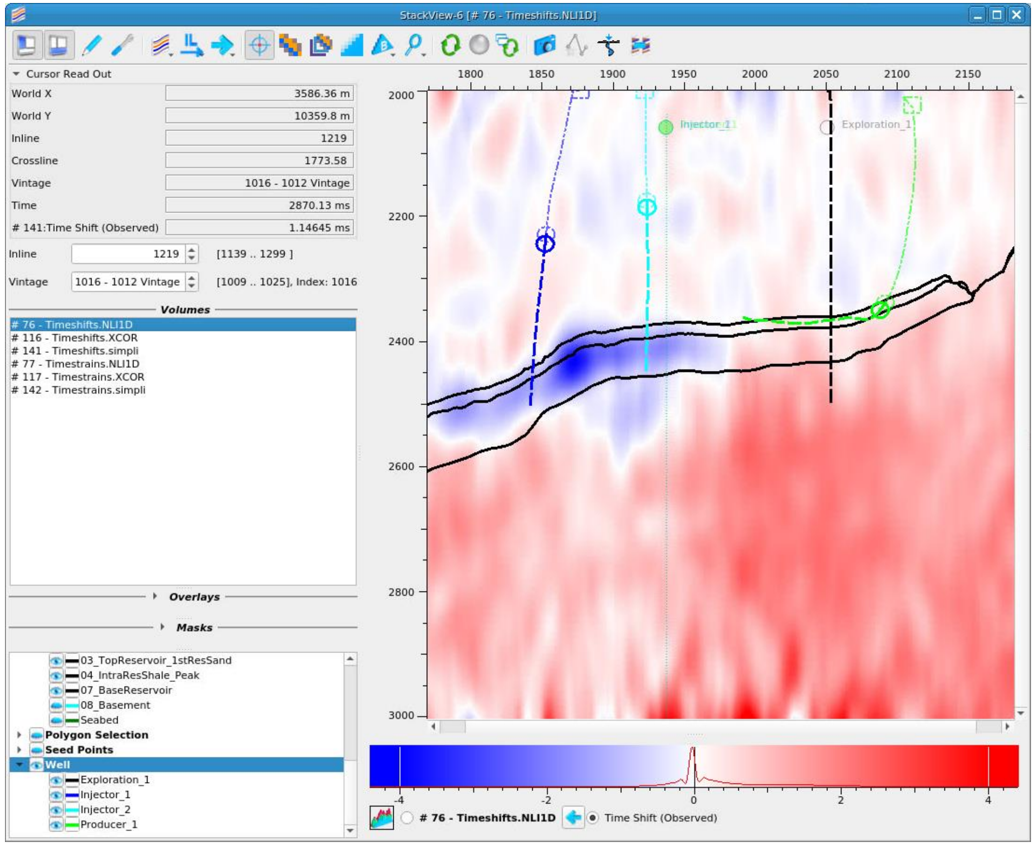
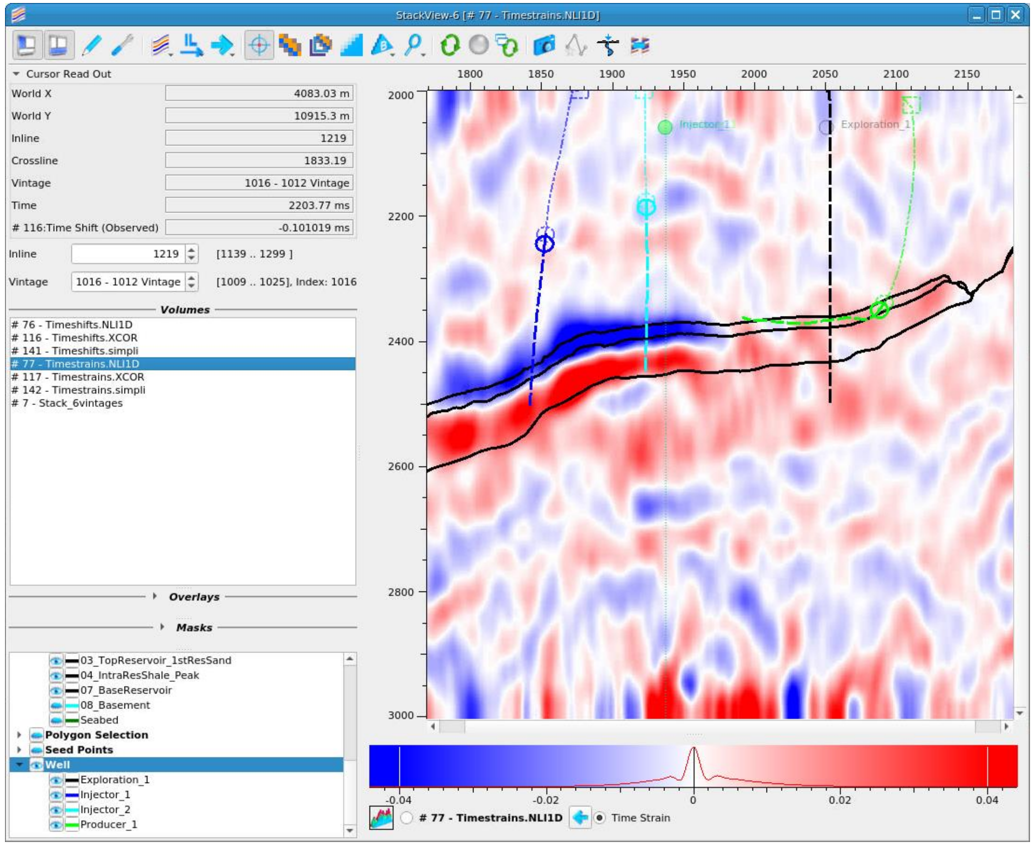
Exercise 1

Estimated timelapse timeshifts and timestrains : *NLI1D*

Timeshifts (NLI1D): 1016 using 1012 as a reference



Timestrains (NLI1D): 1016 using 1012 as a reference



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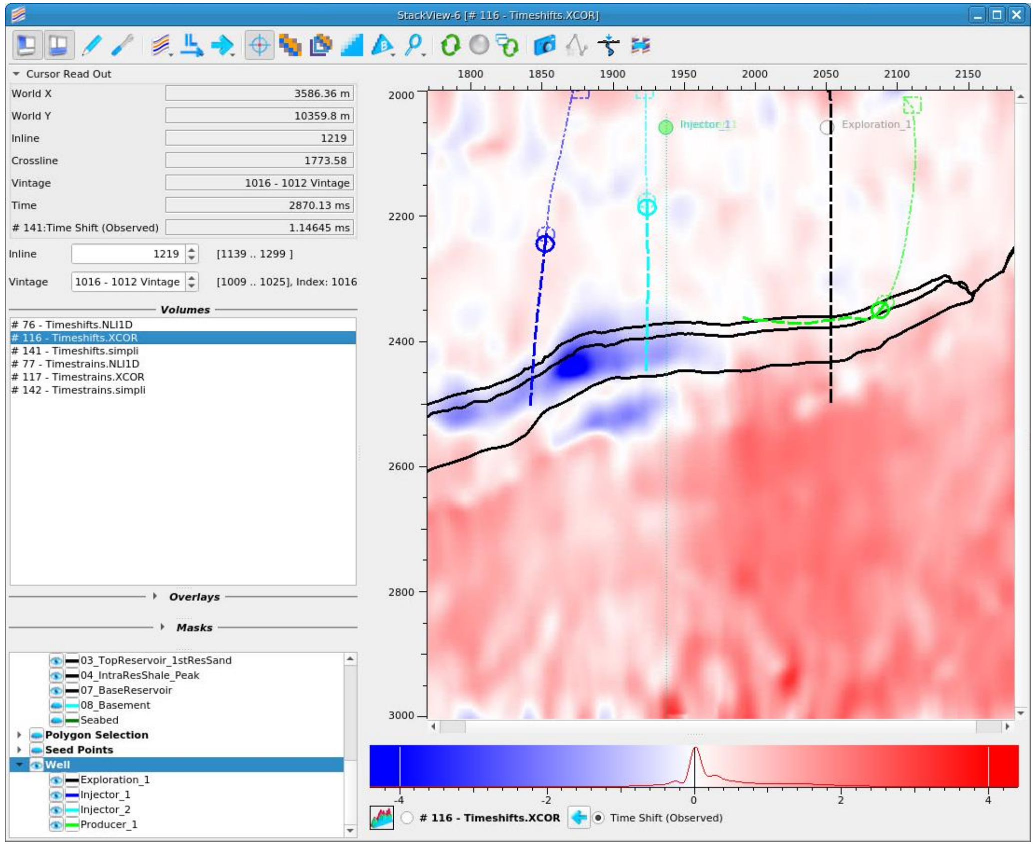
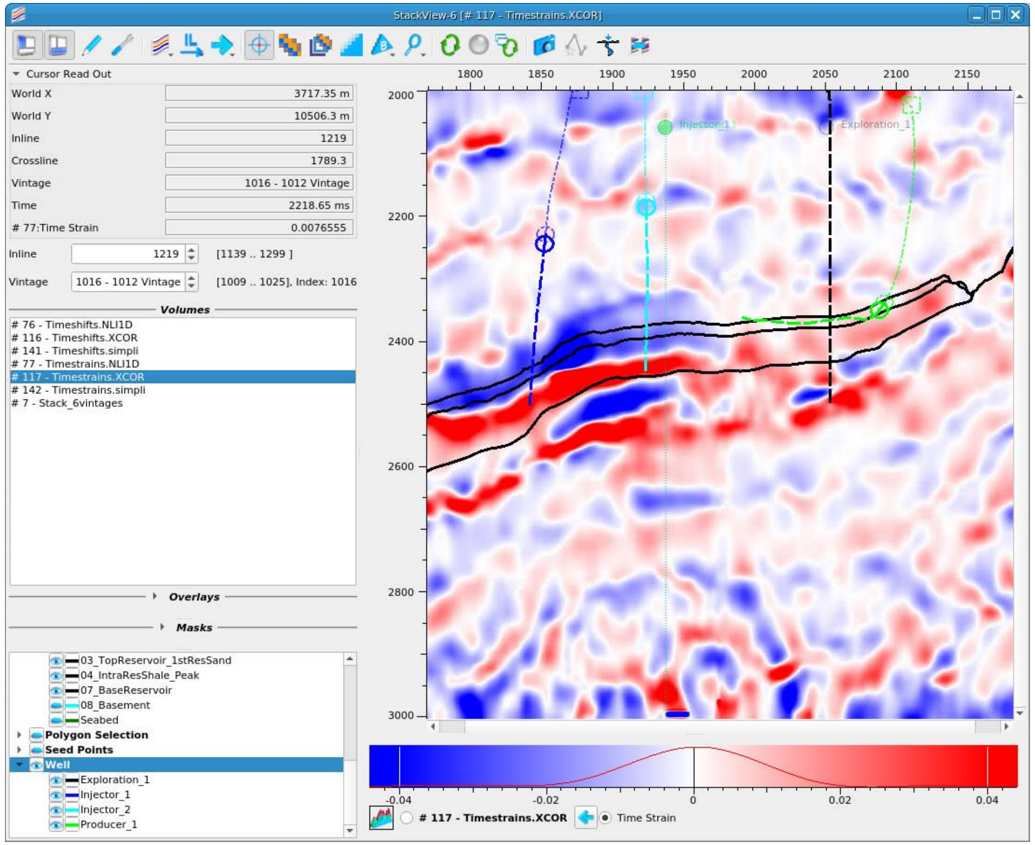
Estimated timelapse timeshifts and timestrains : *Cross-correlation*

Timeshifts (xcorr): 1016 using 1012 as a reference



Timestrains (xcorr): 1016 using 1012 as a reference



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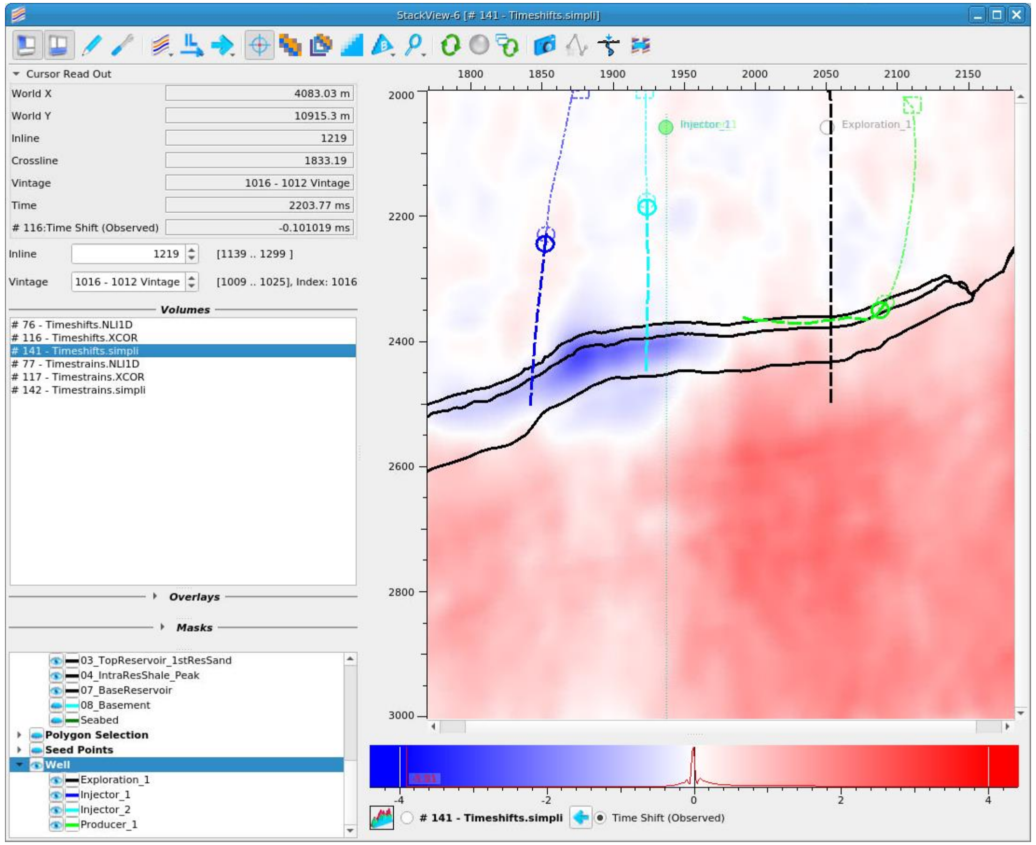
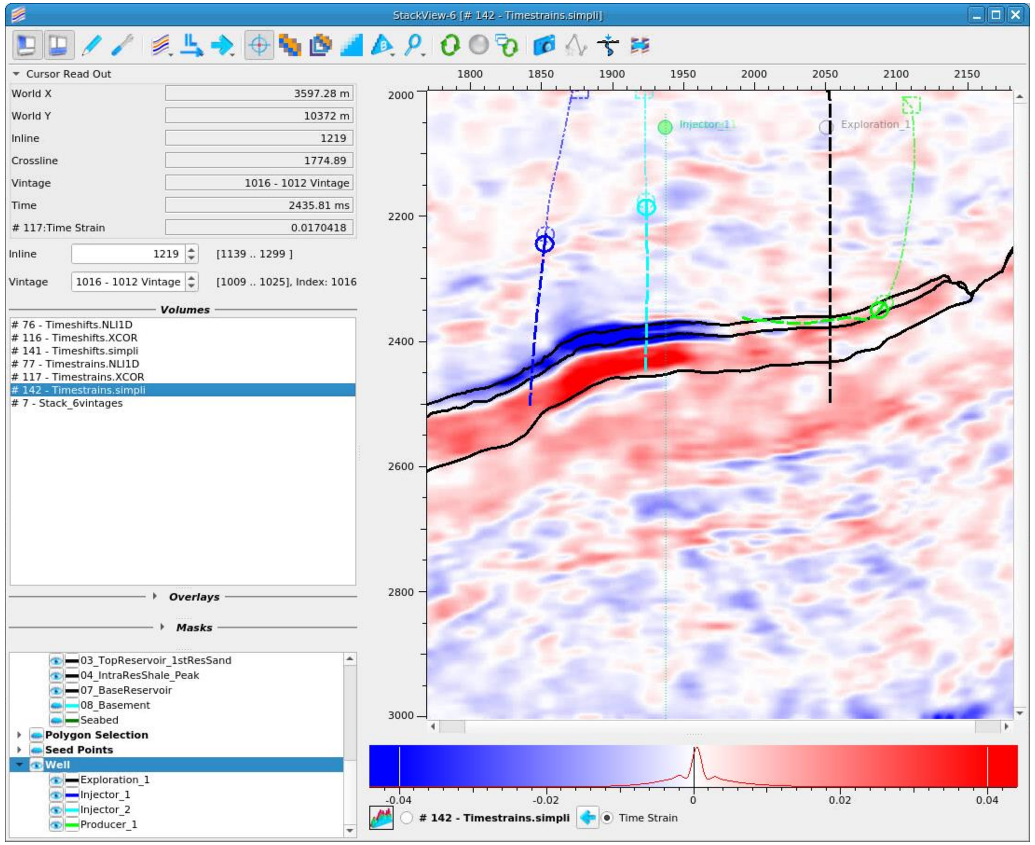
Estimated timelapse timeshifts and timestrains: *simpli*

Timeshifts (simpli): 1016 using 1012 as a reference



Timestrains (simpli): 1016 using 1012 as a reference



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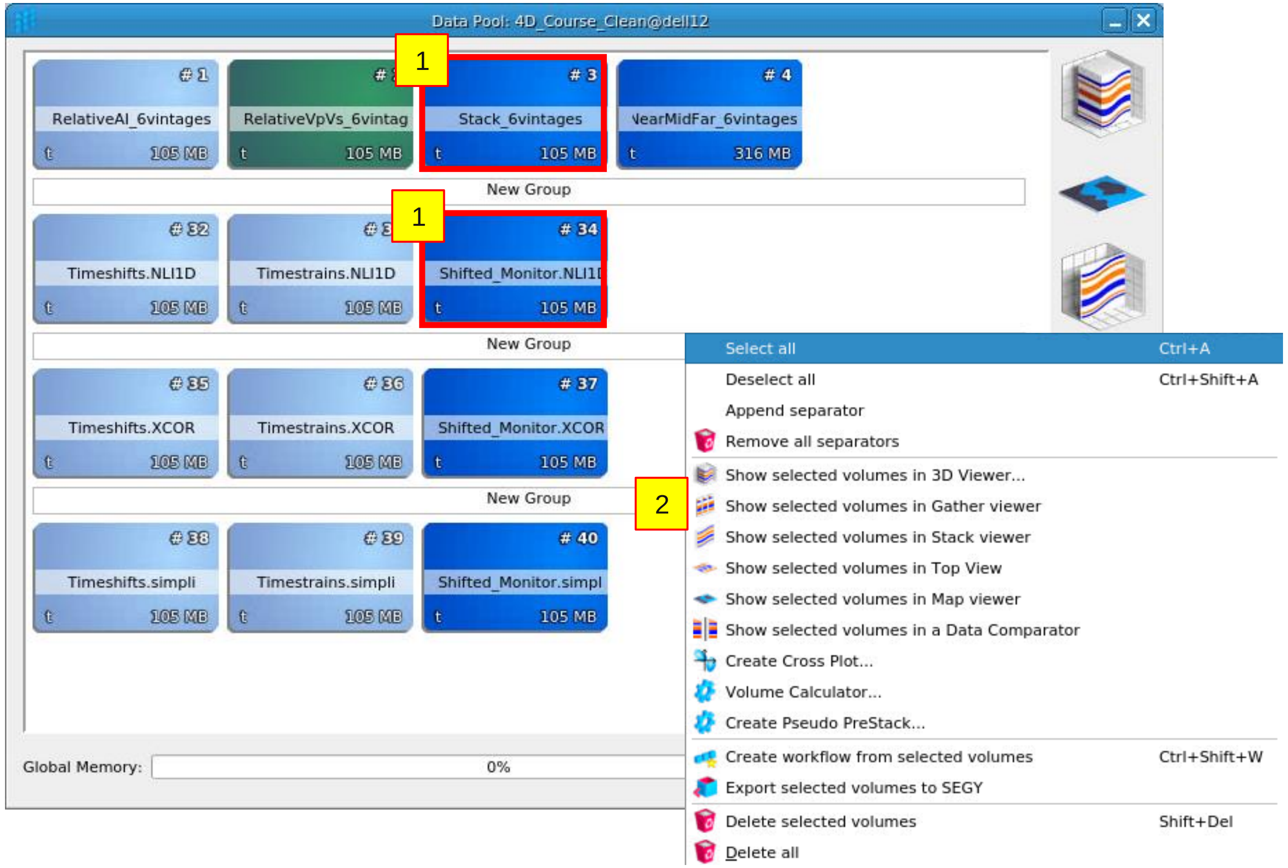
Exercise 1

QC using pre-stack viewer and vintage axis



Using “Gather Viewer”, compare vintage gathers pre-and psot-alignment.

1. Select data volume by Ctrl+LMB
   - Multi-vintage fullstack seismic before correction (“Stack_6vintages”) and
   - Aligned multi-vintage seismic (“Shifted_Monitor.NLI1D”)
2. Display multiple data volumes by RMB in empty space in data pool and “Show selected volumes in Gather Viewer”

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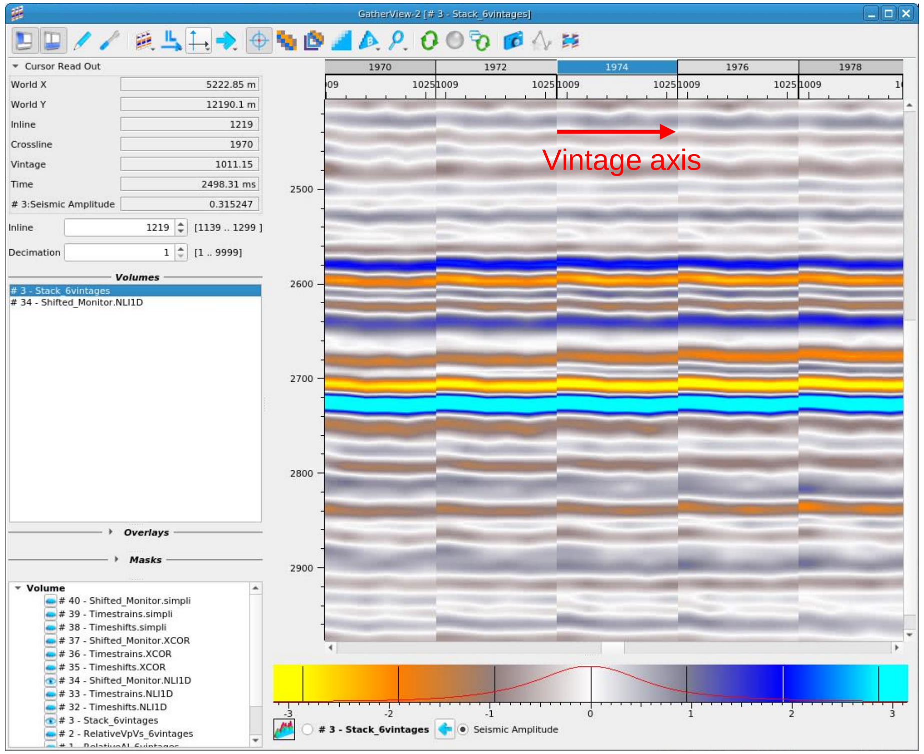
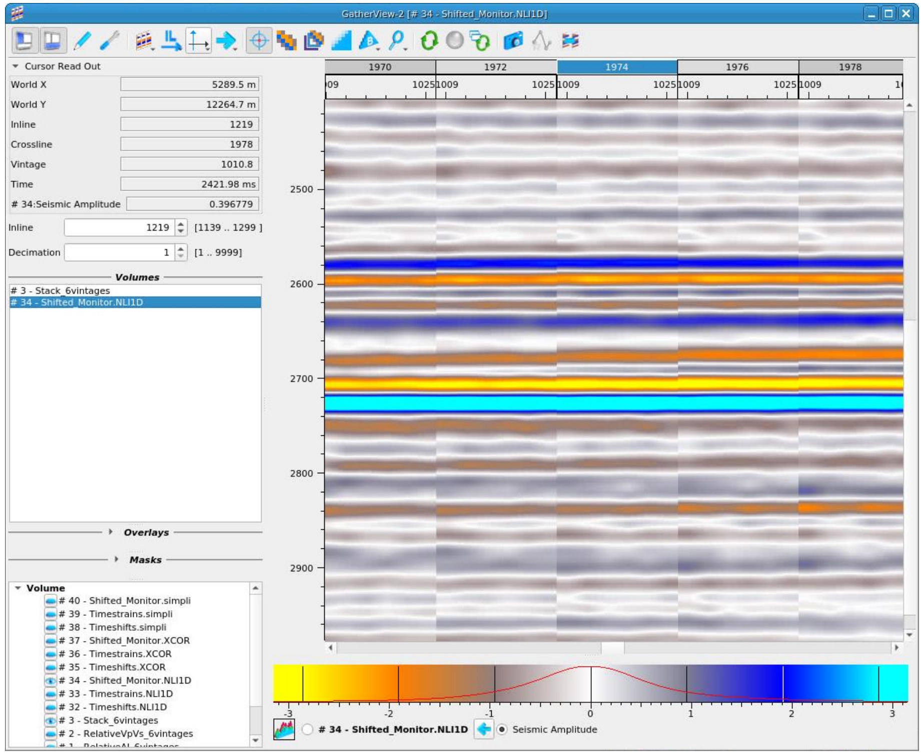
QC using pre-stack viewer and vintage axis

Multi-vintage volume before alignment



Multi-vintage volume after alignment



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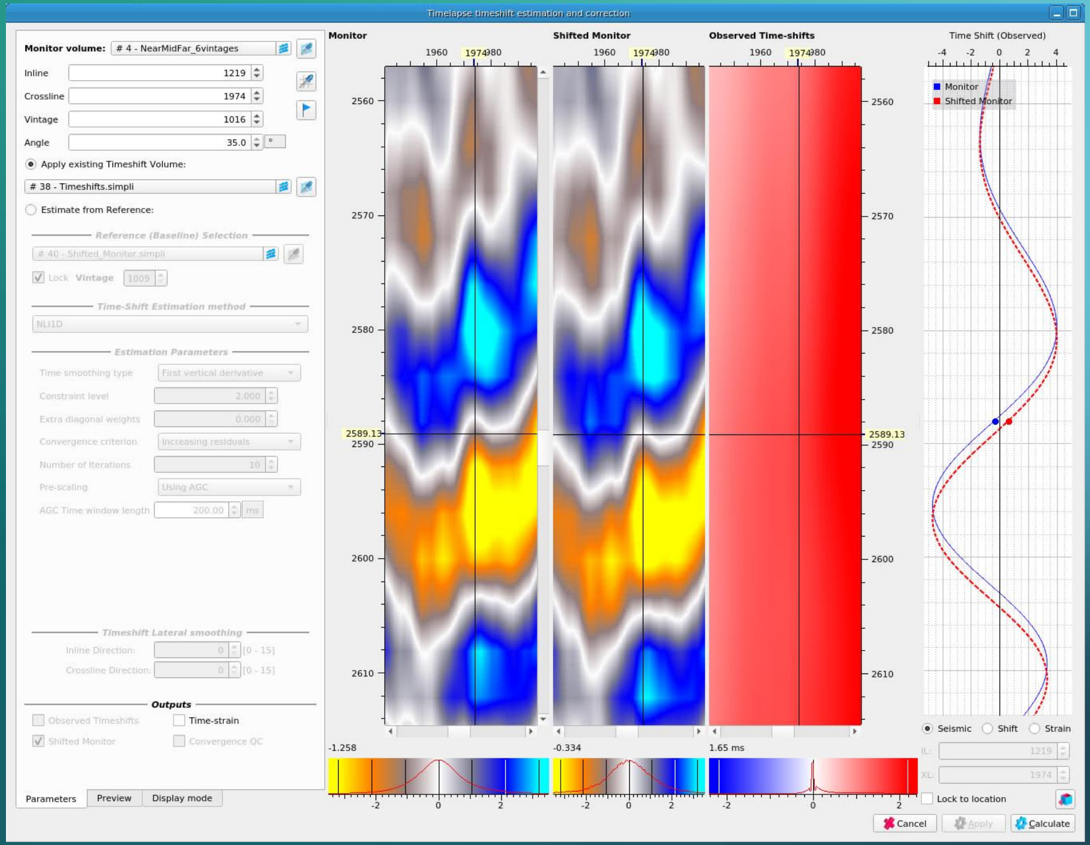
Timeshift estimation and correction

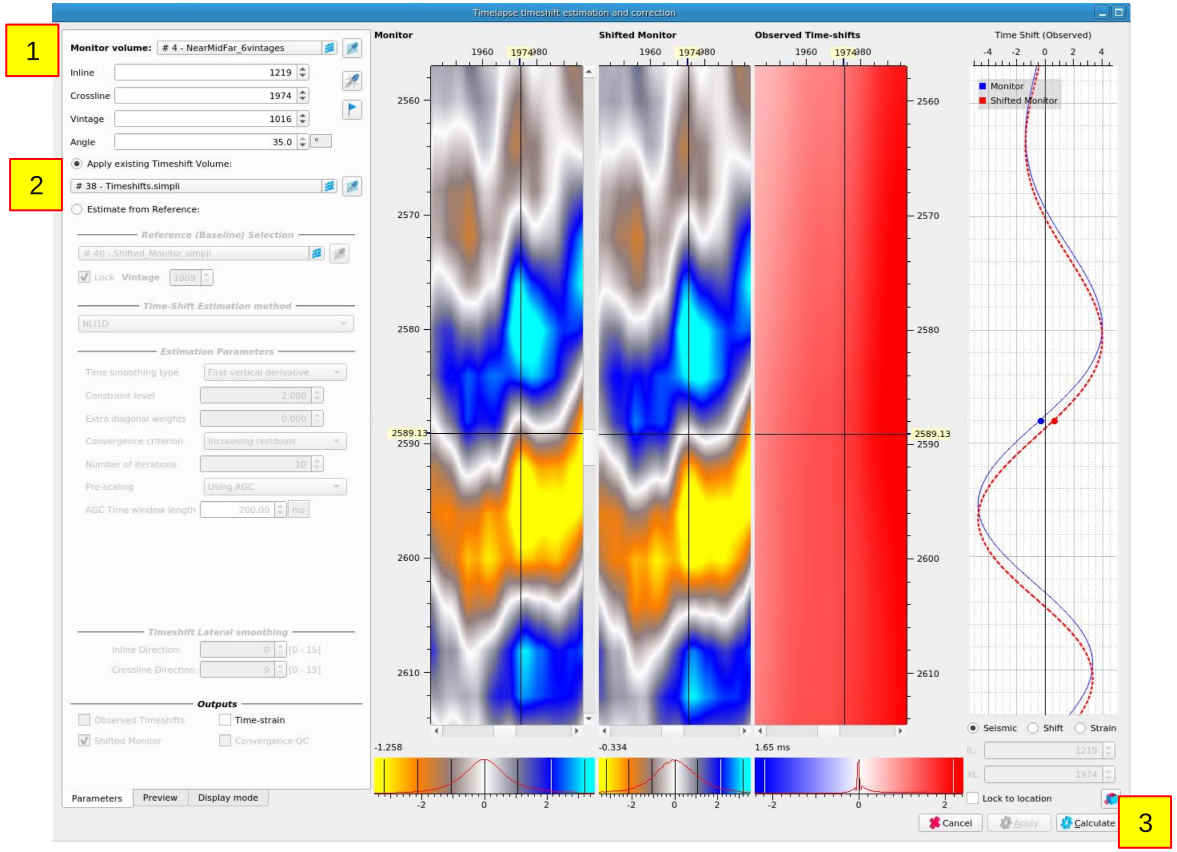
Correcting time-shifts in pre-stack data

Learning goals

- *Applying timeshifts estimated from full-stacks to pre-stack volumes*
- *Estimating timeshifts in pre-stack volumes*
- *Application of estimated timeshifts to inversion volumes*



Using estimated timeshifts from full-stack volume and applying these to time-align gathers



Open Processing → Time-shift Estimate

Load gather data ("NearMidFar_6vintages") to data pool. Make sure that a timeshift volume is available in data pool as well

1. Select Monitor volume to have timeshifts applied to ("NearMidFar_6vintages")
2. Select timeshift volume (e.g., "Timeshifts.simpli")
3. Calculate

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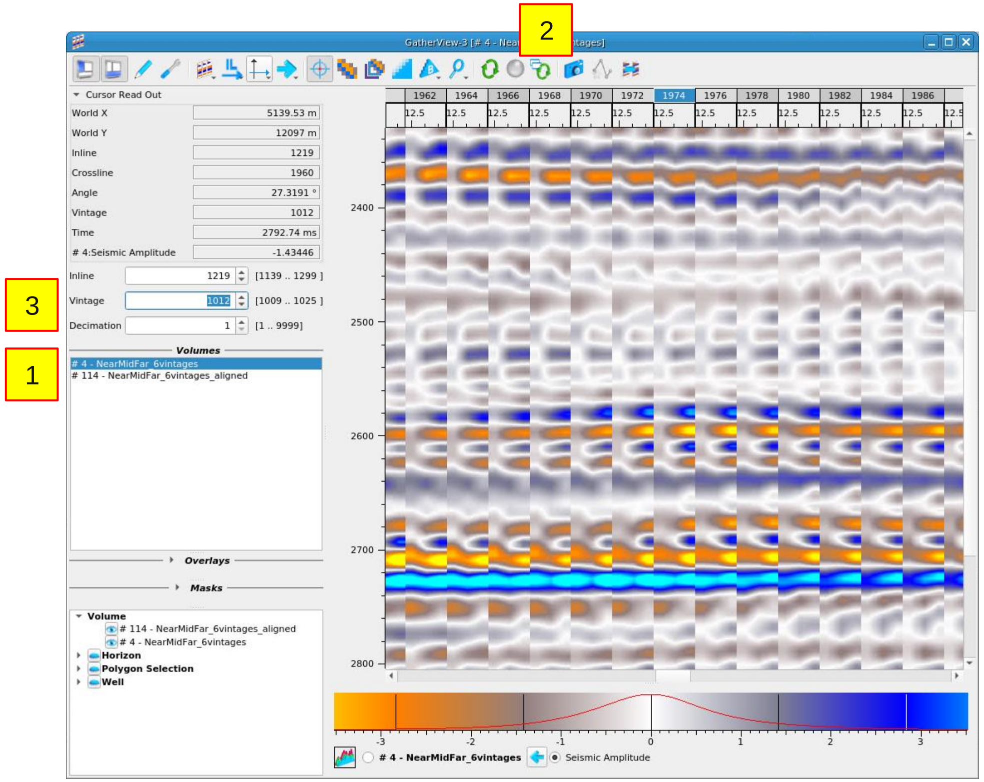
QC using „Gather Viewer“

Exercise 2

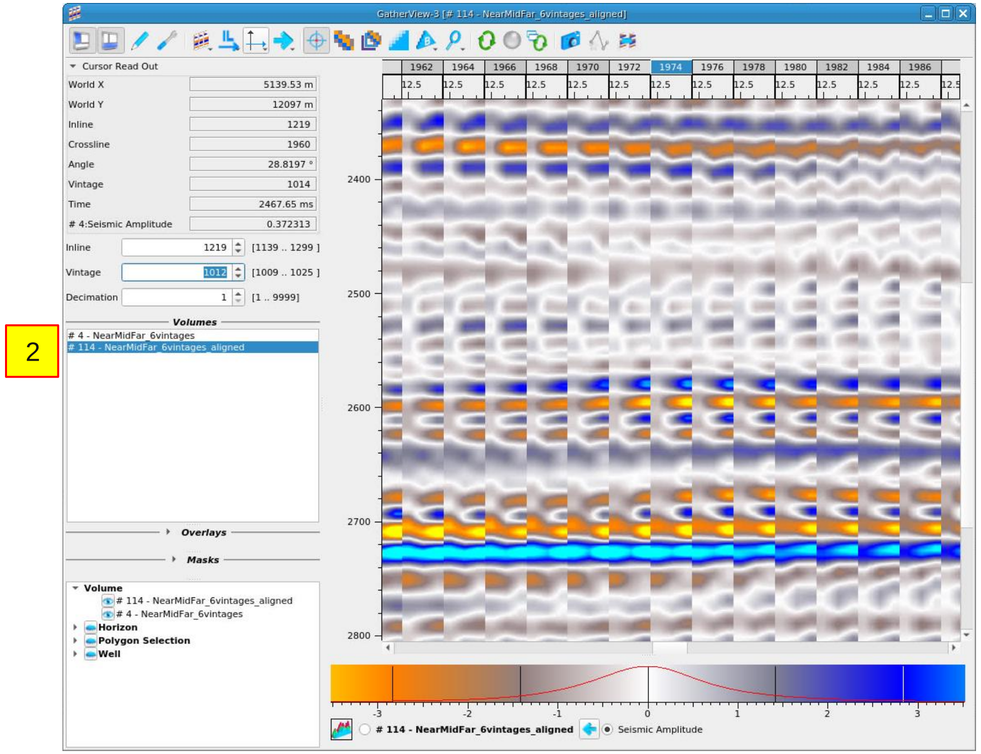
1. Gathers before and after alignment
2. “Clone window and sync”. Use one window for gathers before alignment and the second window after alignment
3. Use “Vintage” control to scroll through vintages

Enjoy

Vintage 1012: Gathers before time-alignment



Vintage 1012: Gathers after time-alignment



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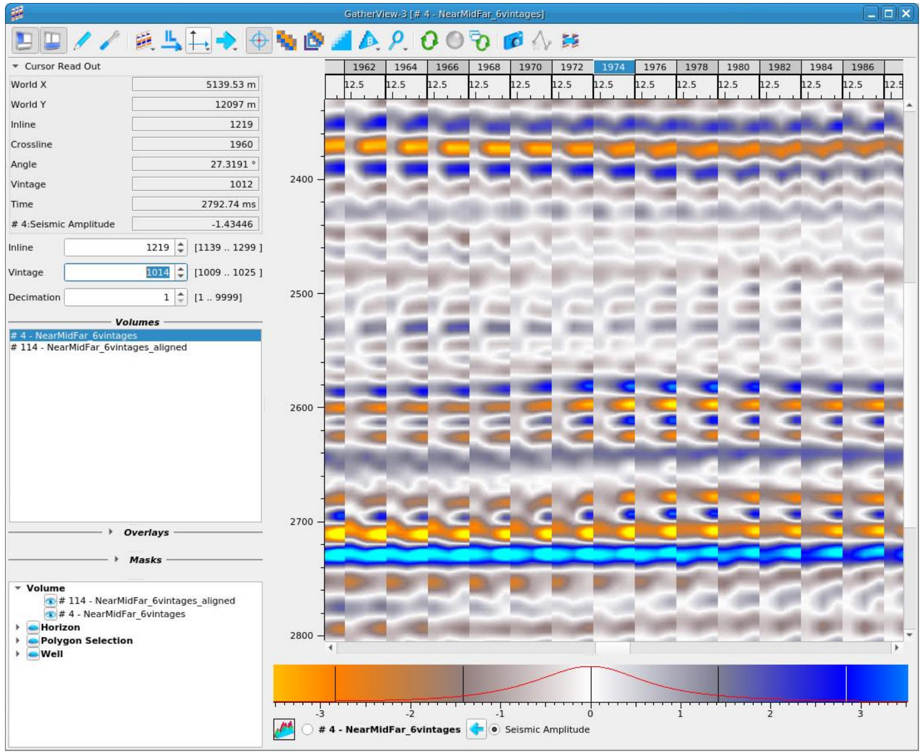
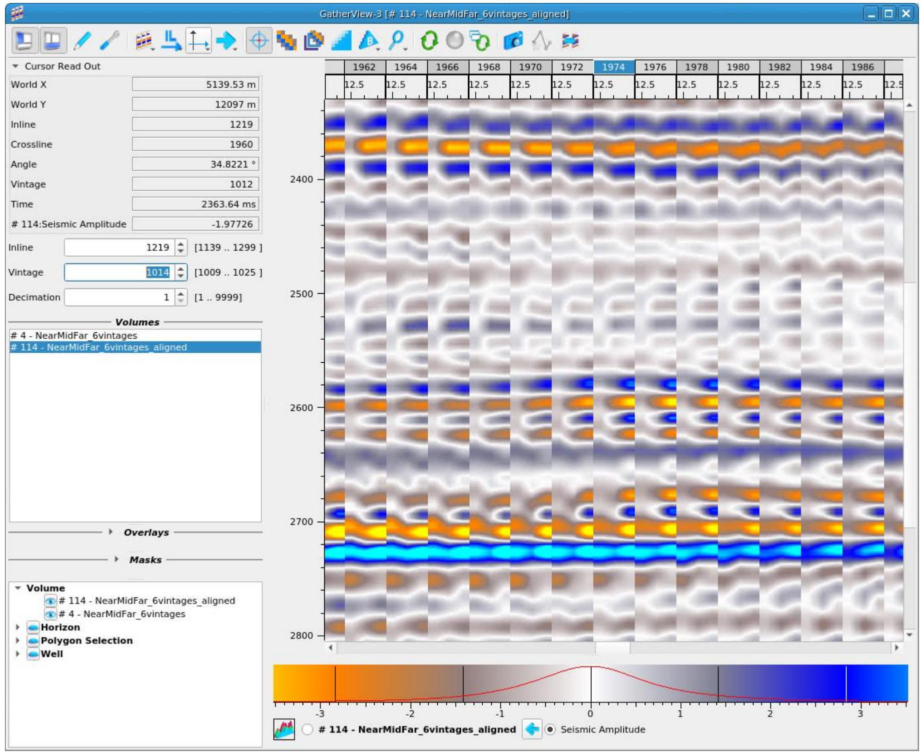
QC using „Gather Viewer“

Vintage 1014: Gathers before time-alignment



Vintage 1014: Gathers after time-alignment



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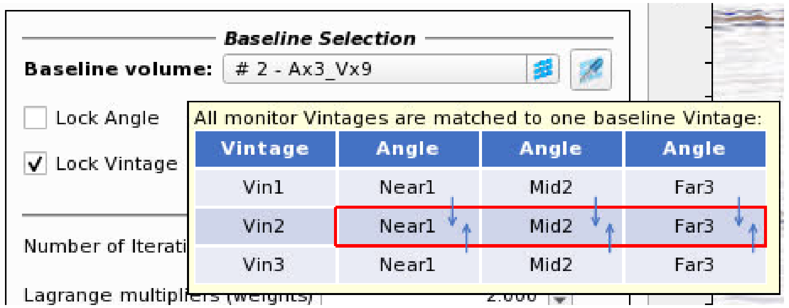
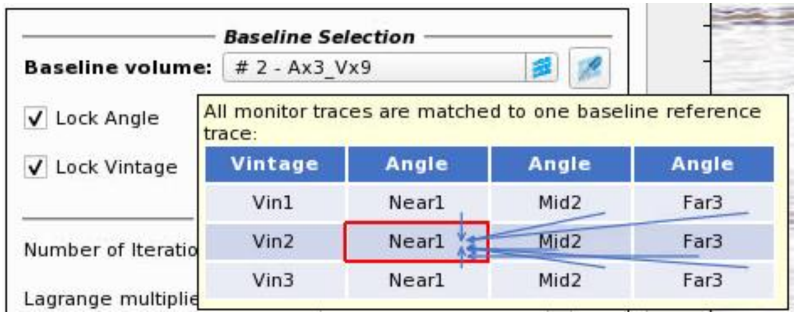
Other applications of the timeshift estimation and correction tool

1. Estimating timeshifts in pre-stack volumes





2. Application of estimated timeshifts to inversion volumes
   - AVA inversions can be run on seismic volumes before timeshift correction. The resulting property volumes will not be time-aligned.
     - You can try estimating time-shifts on the inverted volumes, or
     - Apply estimated timeshifts to time-align the property volumes

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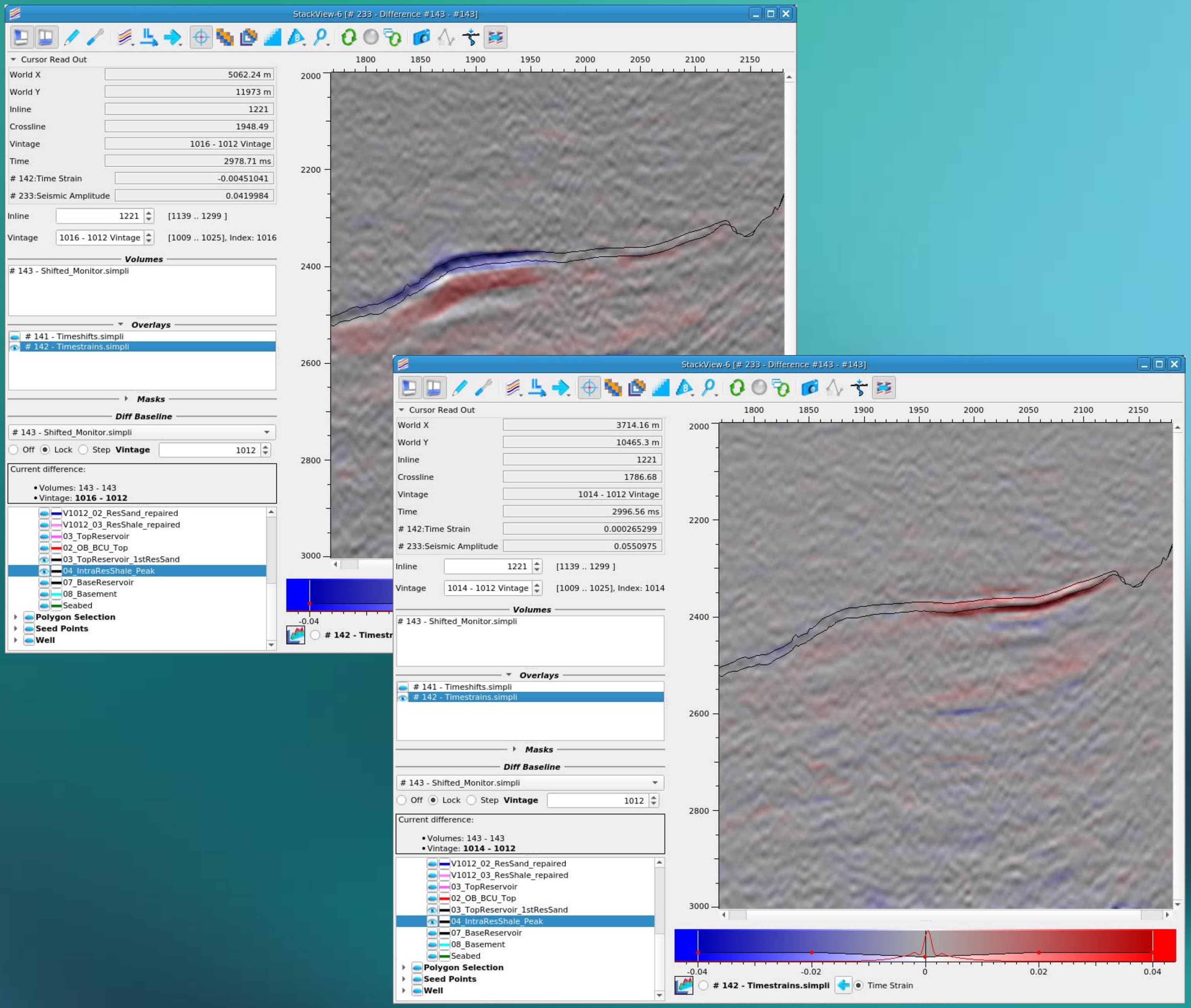
Timeshift estimation

(3) Using overlays to co-visualize seismic amplitude data and timeshifts/timestrains

Learning goals:

- *Co-visualization of timestrains/timeshifts (as overlay) with 3D seismic and 4D seismic creates context:*
  - *Can timeshifts be measured as there is coherent seismic energy, or*
  - *Are the timestrains at a reasonable position w.r.t. 4D amplitude changes*



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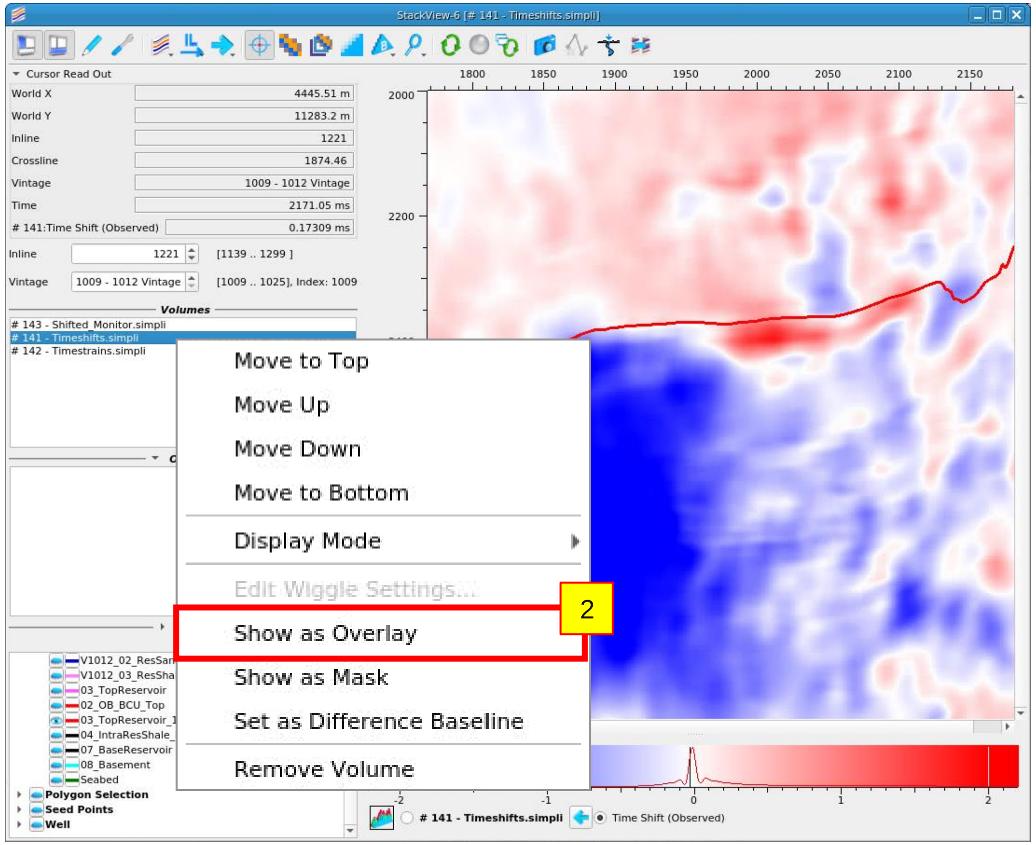
Exercise 3

Using Overlays to co-visualize seismic-data with timeshifts



Co-visualize timeshifts and **3D** seismic data

1. In data pool, highlight
   - Shifted_Monitor.simpli
   - Timeshifts.simpli
   - Timestrains.simpli

   then RMB, and “Show selected volumes in Stack Viewer
2. RMB on “Timeshifts.simpli“ and “Show as overlay”. Repeat for timestrains
3. Adjust colourbars
   - Timeshifts (e.g., [-4 4] ms).
     - “Content specific histogram” (right radio button) → scaling for all volumes of the same data-type
     - “Volume specific histogram” (left radio button) → scaling for displayed volume only

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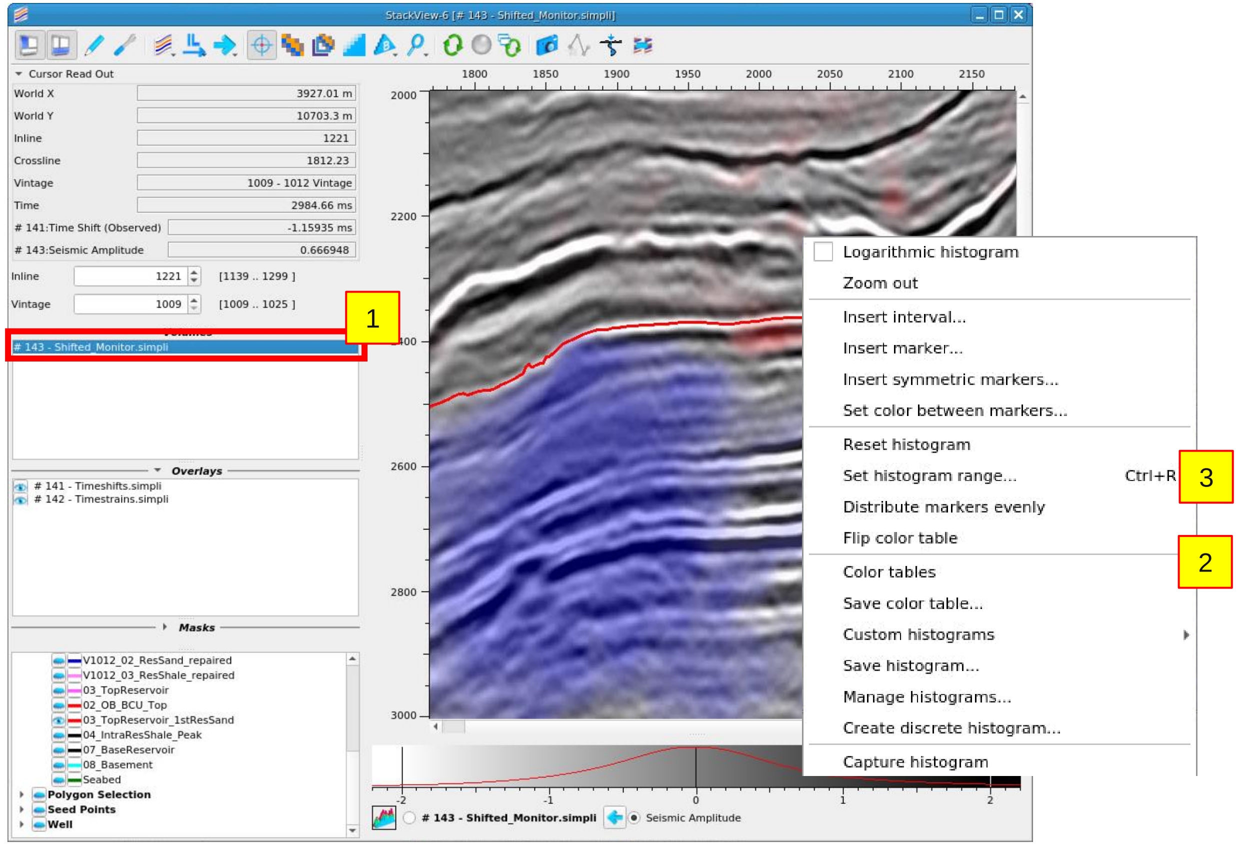
Exercise 3

Using Overlays to co-visualize seismic-data with timeshifts



Co-visualize timeshifts and **3D** seismic data

1. Colormap for seismic. Highlight seismic volume.
2. Choose a greyscale colormap for seismic data, by RMB on colourmap. “”Color Tables”→ “White – Black”
3. Adjust colourlimits (e.g., [-2 2])

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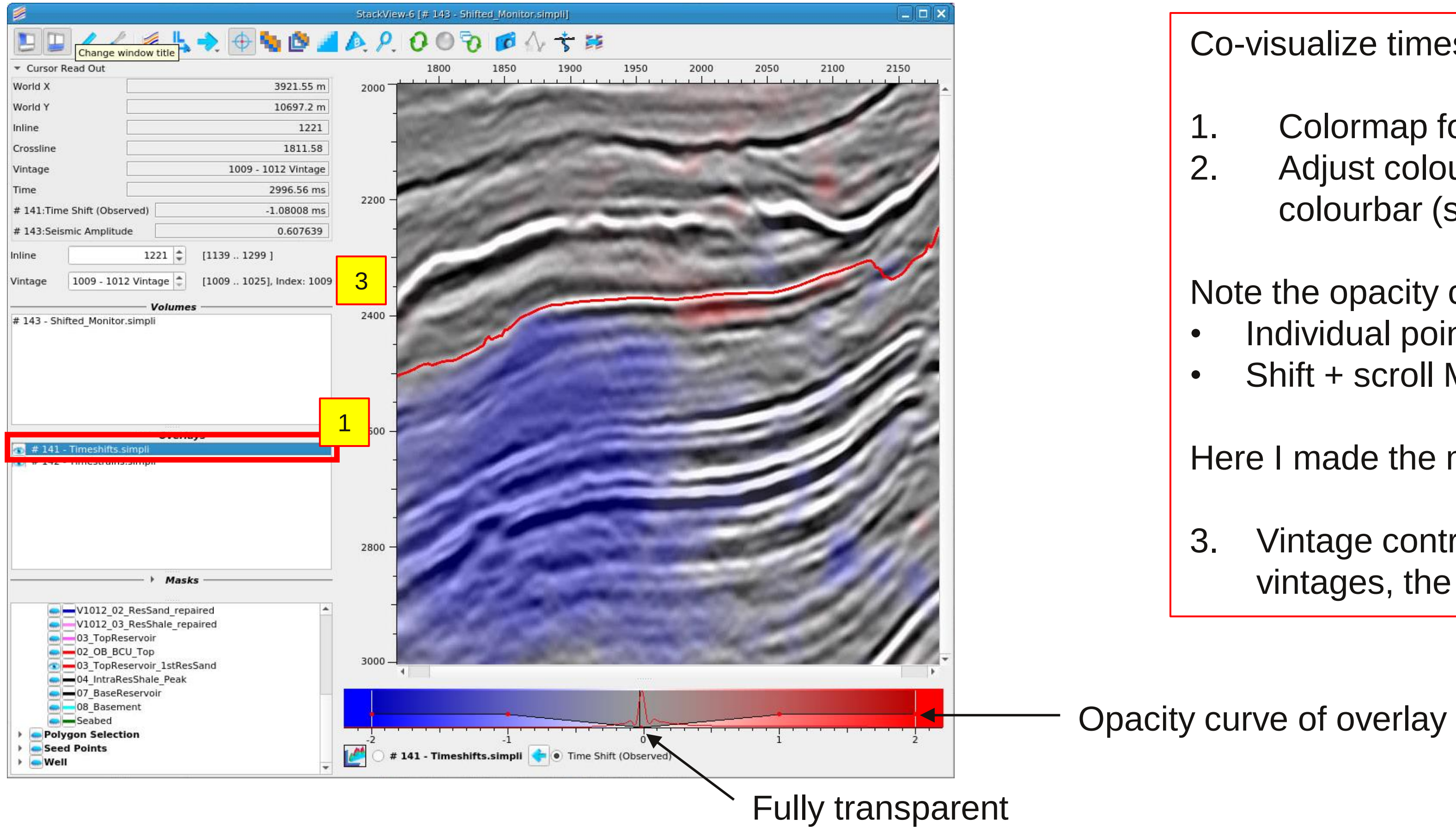
SHARP REFLECTIONS

Using Overlays to co-visualize seismic-data with timeshifts



Co-visualize timeshifts and **3D** seismic data

1. Colormap for timeshifts. Highlight timeshift volume.
2. Adjust colourlimits on timeshift volume, by RMB on colourbar (select e.g., [-2 2])

Note the opacity curve in the colourmap.

- Individual points can be dragged up and down
- Shift + scroll MMB moves the opacity curve up and down

Here I made the middle of the colourmap fully transparent

3. Vintage control on timeshift volume. Not that for most vintages, the timeshifts start at the top reservoir horizon

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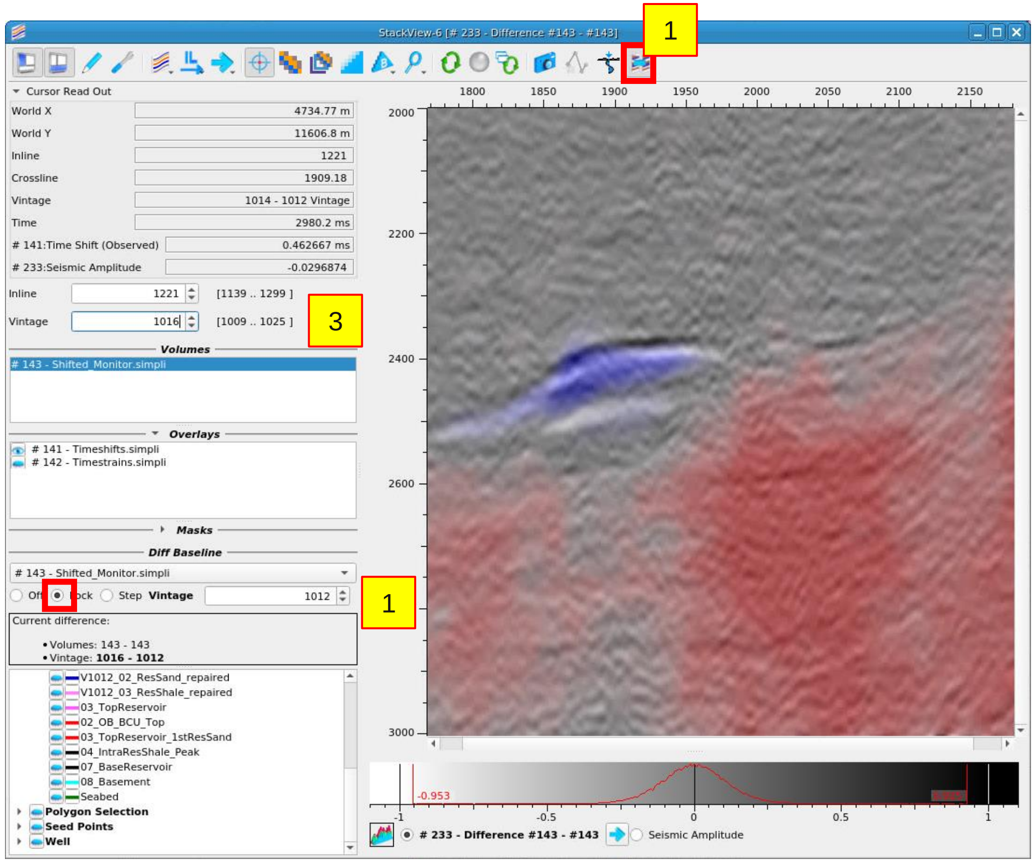
Using Overlays to co-visualize seismic-data with timeshifts



Co-visualize timeshifts and **4D** seismic data

1. Enable “difference-in-viewer”.
2. Lock vintage to “1012”.
   - Timeshift are calculated with 1012 as reference, hence here we need to choose 1012 as reference
3. Use different monitor surveys (here 1016-1012), and compare 4D amplitude and timeshift signal

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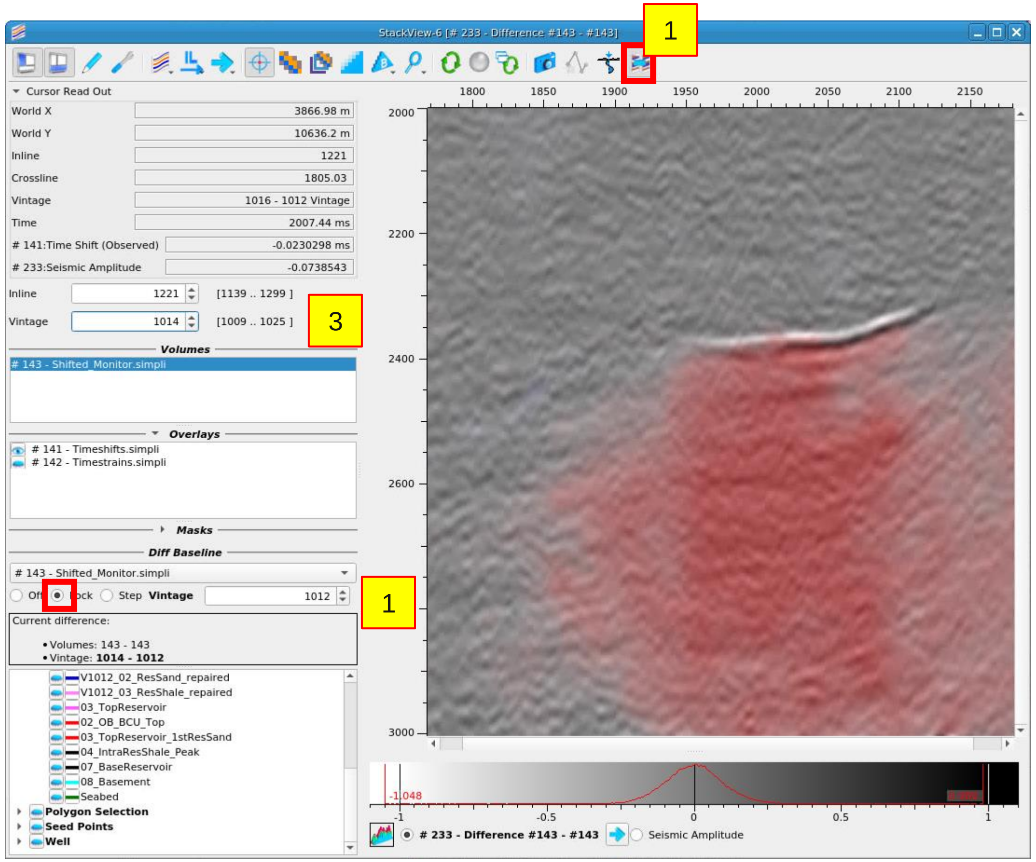
Using Overlays to co-visualize seismic-data with timeshifts



Co-visualize timeshifts and **4D** seismic data

1. Enable “difference-in-viewer”.
2. Lock vintage to “1012”.
   - Timeshift are calculated with 1012 as reference, hence here we need to choose 1012 as reference
3. Use different monitor surveys (here 1014-1012), and compare 4D amplitude and timeshift signal

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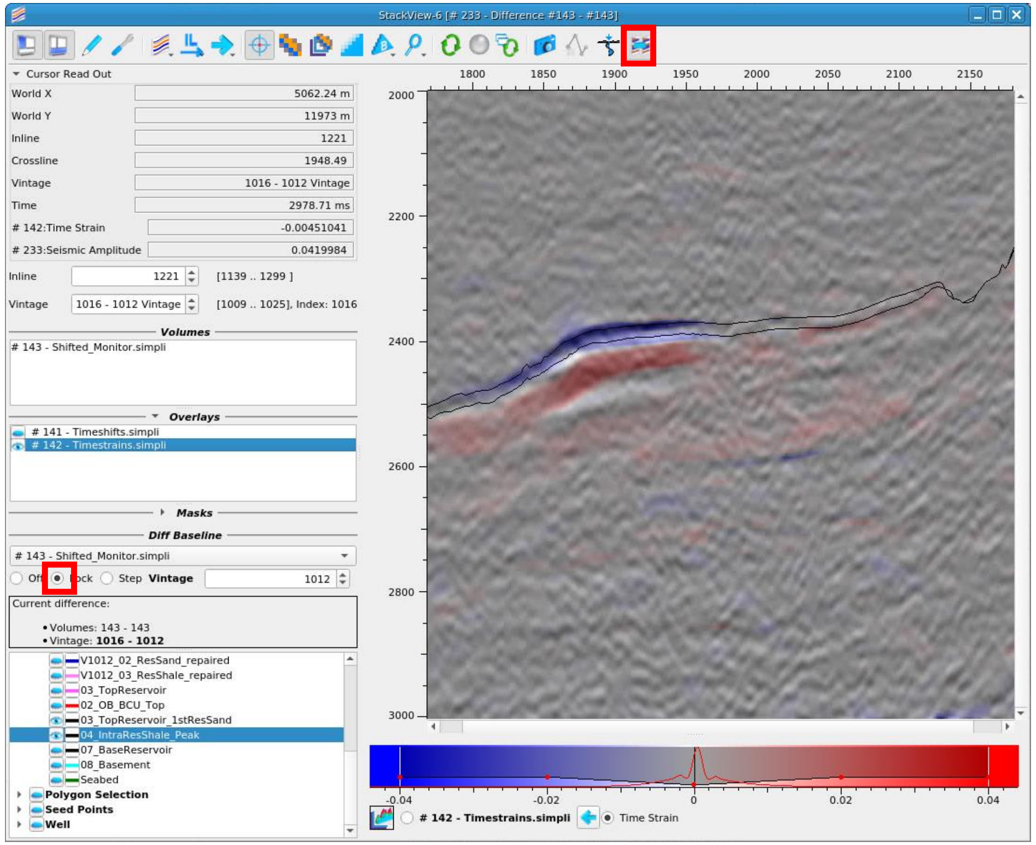
Using Overlays to co-visualize seismic-data with timestrains



Repeat steps above to co-visualize timestrains (as overlay) and **4D** seismic data (as greyscale background)

Here (1016-1012)

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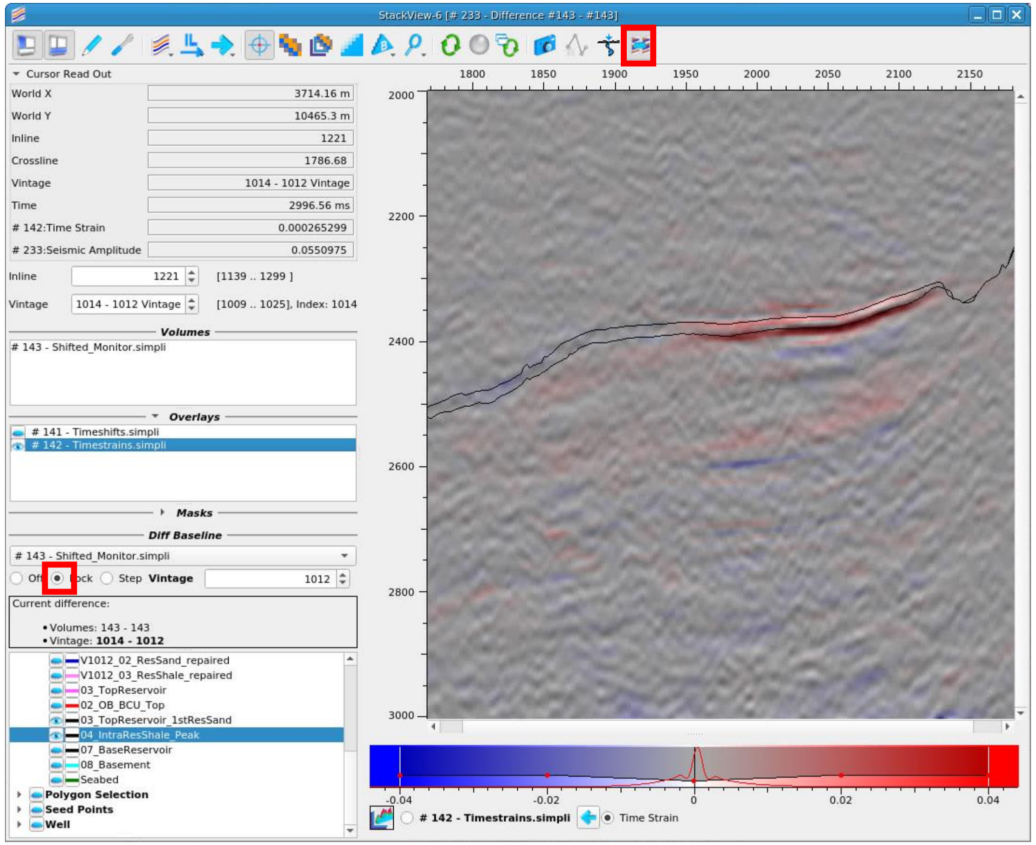
Using Overlays to co-visualize seismic-data with timestrains



Repeat steps above to co-visualize timestrains (as overlay) and **4D** seismic data (as greyscale background)

Here (1014-1012)

Question:
Based on the observations of
- Timestrains and 3D seismic, and
- Timestrains and 4D seismic

do you think that the parameterization of the timestrain estimation is optimal, if the timestrains are to be used as a 4D seismic attribute?

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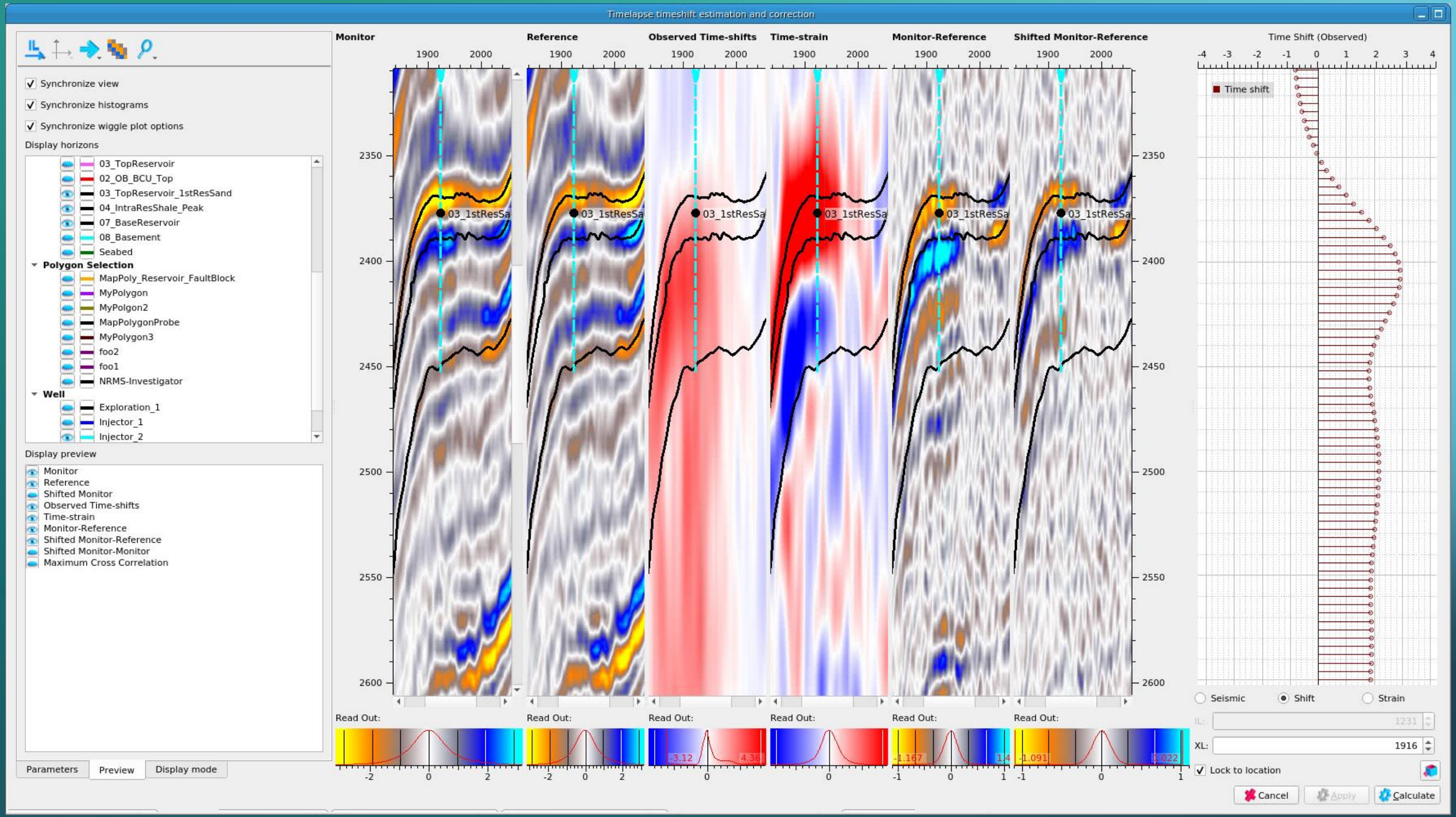
Timeshift estimation

(4) Tips and tricks using the timeshift estimation tool



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Timeshift estimation tool: Tips and tricks

Task:

Explore some features of the timeshift estimation tool that can help in a detailed analysis of estimated timeshifts/timestrains, as well as the ability to timeshift correct seismic data

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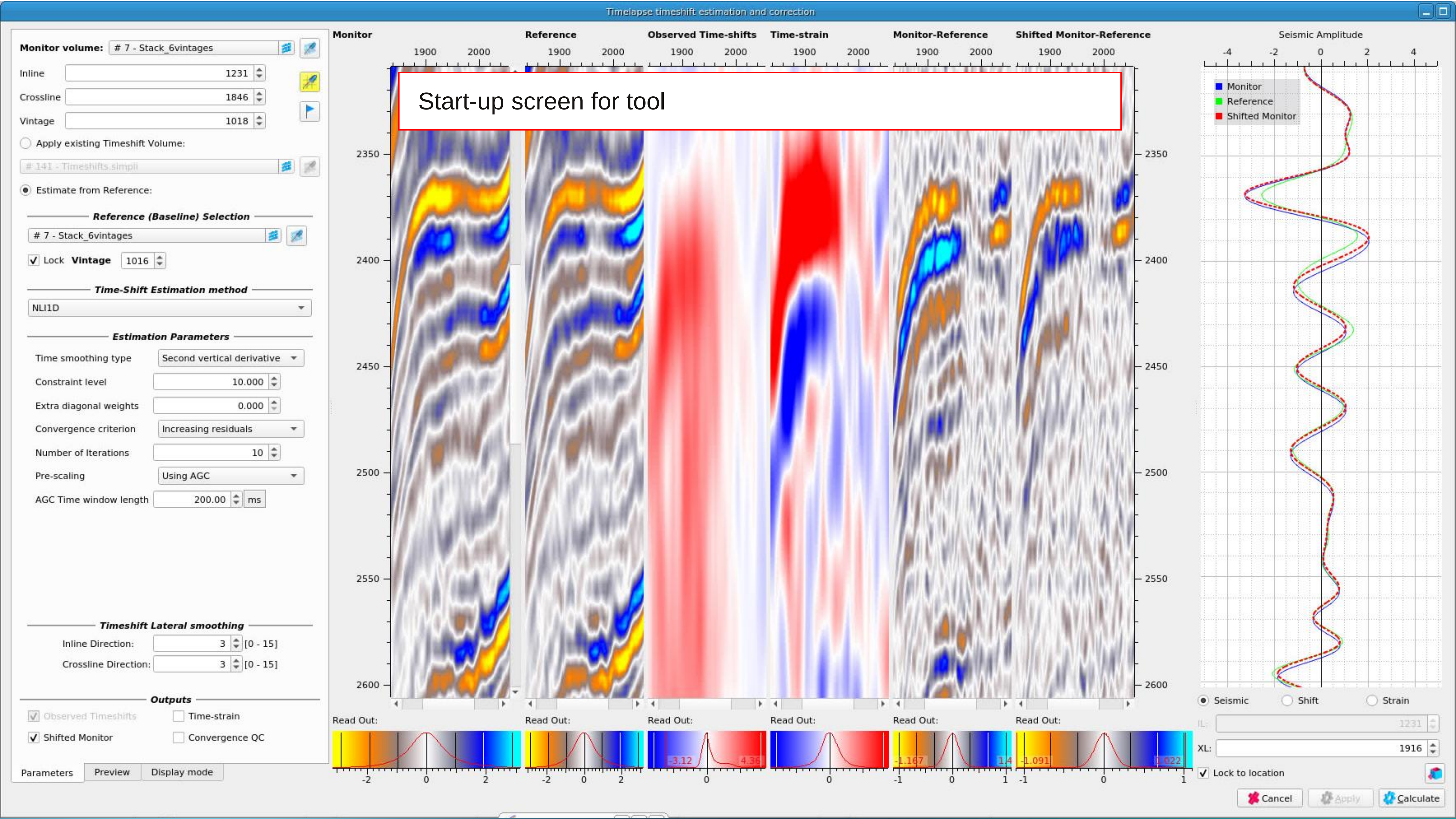
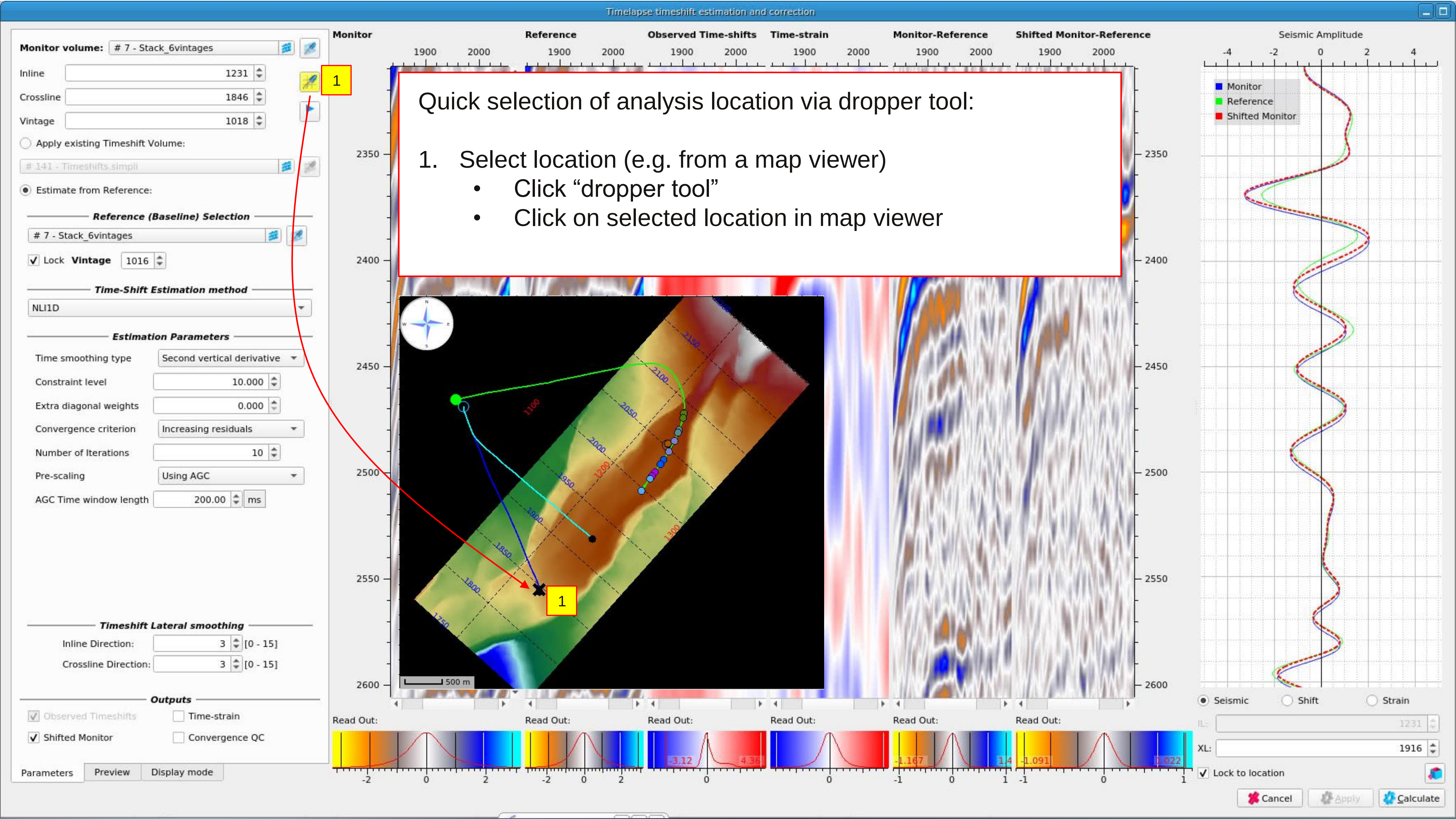
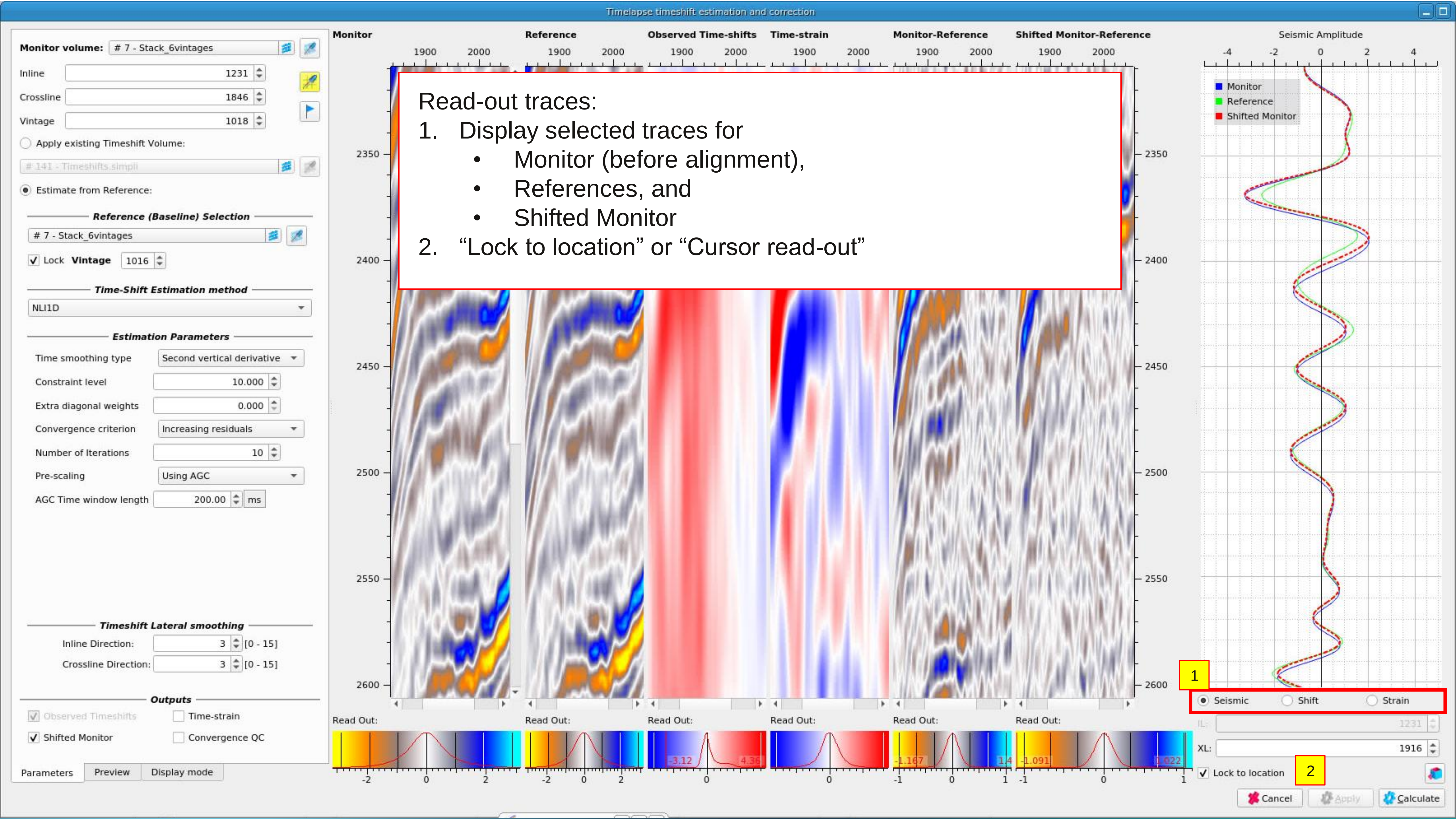


Start-up screen for tool


Timelapse timeshift estimation and correction
Quick selection of analysis location via dropper tool:
1. Select location (e.g. from a map viewer)
• Click “dropper tool”
• Click on selected location in map viewer
1
1
Monitor volume: # 7 - Stack_6vintages
Inline 1231
Crossline 1846
Vintage 1018
Apply existing Timeshift Volume:
141 - Timeshifts.simpli
Estimate from Reference:
Reference (Baseline) Selection
7 - Stack_6vintages
Lock Vintage 1016
Time-Shift Estimation method
NLI1D
Estimation Parameters
Time smoothing type Second vertical derivative
Constraint level 10.000
Extra diagonal weights 0.000
Convergence criterion Increasing residuals
Number of Iterations 10
Pre-scaling Using AGC
AGC Time window length 200.00 ms
Timeshift Lateral smoothing
Inline Direction: 3 [0 - 15]
Crossline Direction: 3 [0 - 15]
Outputs
Observed Timeshifts
Time-strain
Shifted Monitor
Convergence QC
Parameters
Preview
Display mode
Monitor
Reference
Observed Time-shifts
Time-strain
Monitor-Reference
Shifted Monitor-Reference
Seismic Amplitude
Monitor
Reference
Shifted Monitor
Seismic
Shift
Strain
XL: 1916
Lock to location
Read Out:
500 m
Cancel
Apply
Calculate

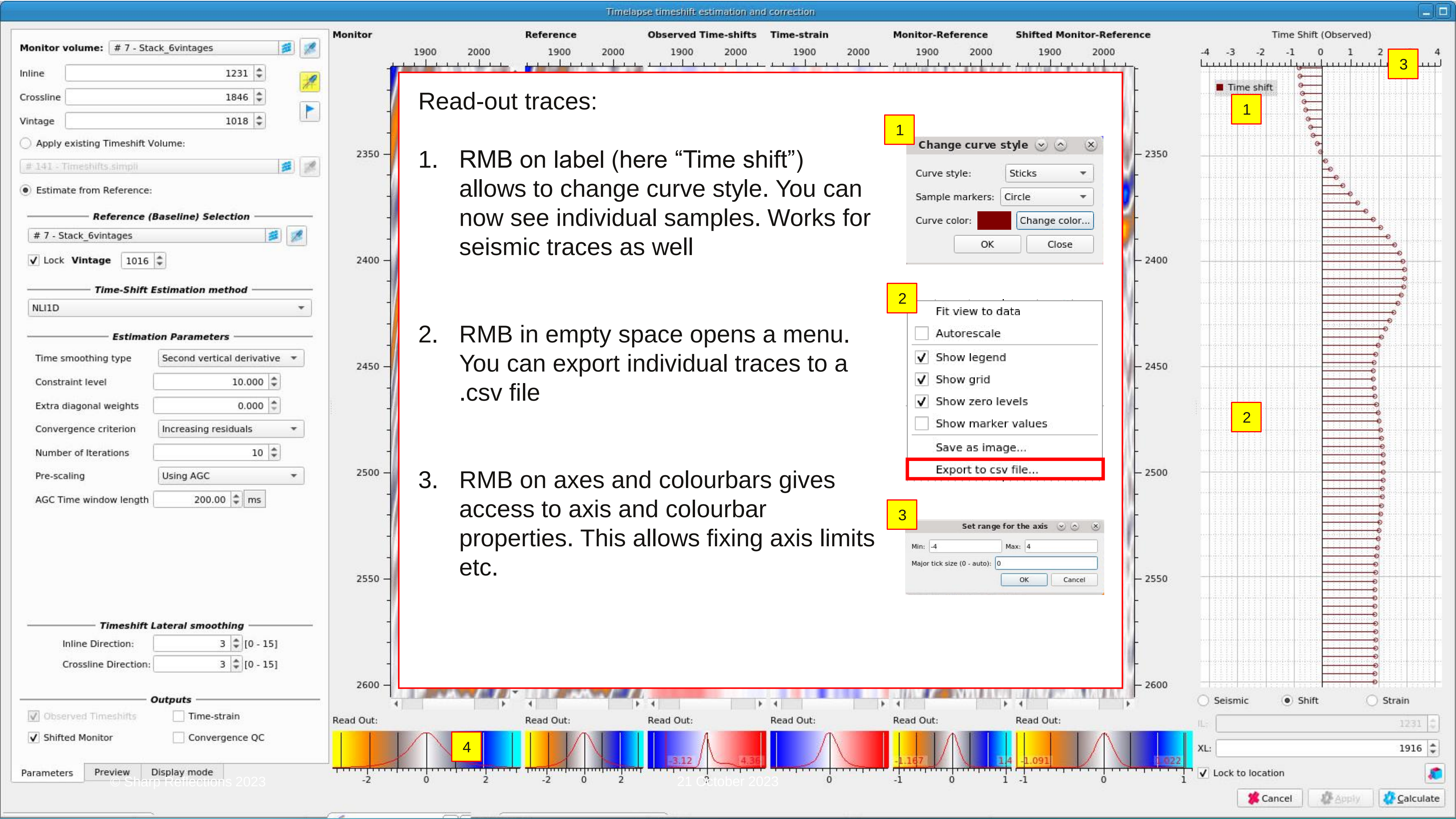

Timelapse timeshift estimation and correction
Read-out traces:
1. Display selected traces for
• Monitor (before alignment),
• References, and
• Shifted Monitor
2. "Lock to location" or "Cursor read-out"
Monitor volume: # 7 - Stack_6vintages
Inline 1231
Crossline 1846
Vintage 1018
Apply existing Timeshift Volume:
141 - Timeshifts.simpli
Estimate from Reference:
Reference (Baseline) Selection
7 - Stack_6vintages
Lock Vintage 1016
Time-Shift Estimation method
NLI1D
Estimation Parameters
Time smoothing type Second vertical derivative
Constraint level 10.000
Extra diagonal weights 0.000
Convergence criterion Increasing residuals
Number of Iterations 10
Pre-scaling Using AGC
AGC Time window length 200.00 ms
Timeshift Lateral smoothing
Inline Direction: 3 [0 - 15]
Crossline Direction: 3 [0 - 15]
Outputs
Observed Timeshifts
Time-strain
Shifted Monitor
Convergence QC
Parameters
Preview
Display mode
Monitor
Reference
Observed Time-shifts
Time-strain
Monitor-Reference
Shifted Monitor-Reference
Seismic Amplitude
Monitor
Reference
Shifted Monitor
Read Out:
1
Seismic
Shift
Strain
IL: 1231
XL: 1916
Lock to location
2
Cancel
Apply
Calculate

Read-out traces:

1. RMB on label (here “Time shift”) allows to change curve style. You can now see individual samples. Works for seismic traces as well

2. RMB in empty space opens a menu. You can export individual traces to a .csv file

3. RMB on axes and colourbars gives access to axis and colourbar properties. This allows fixing axis limits etc.



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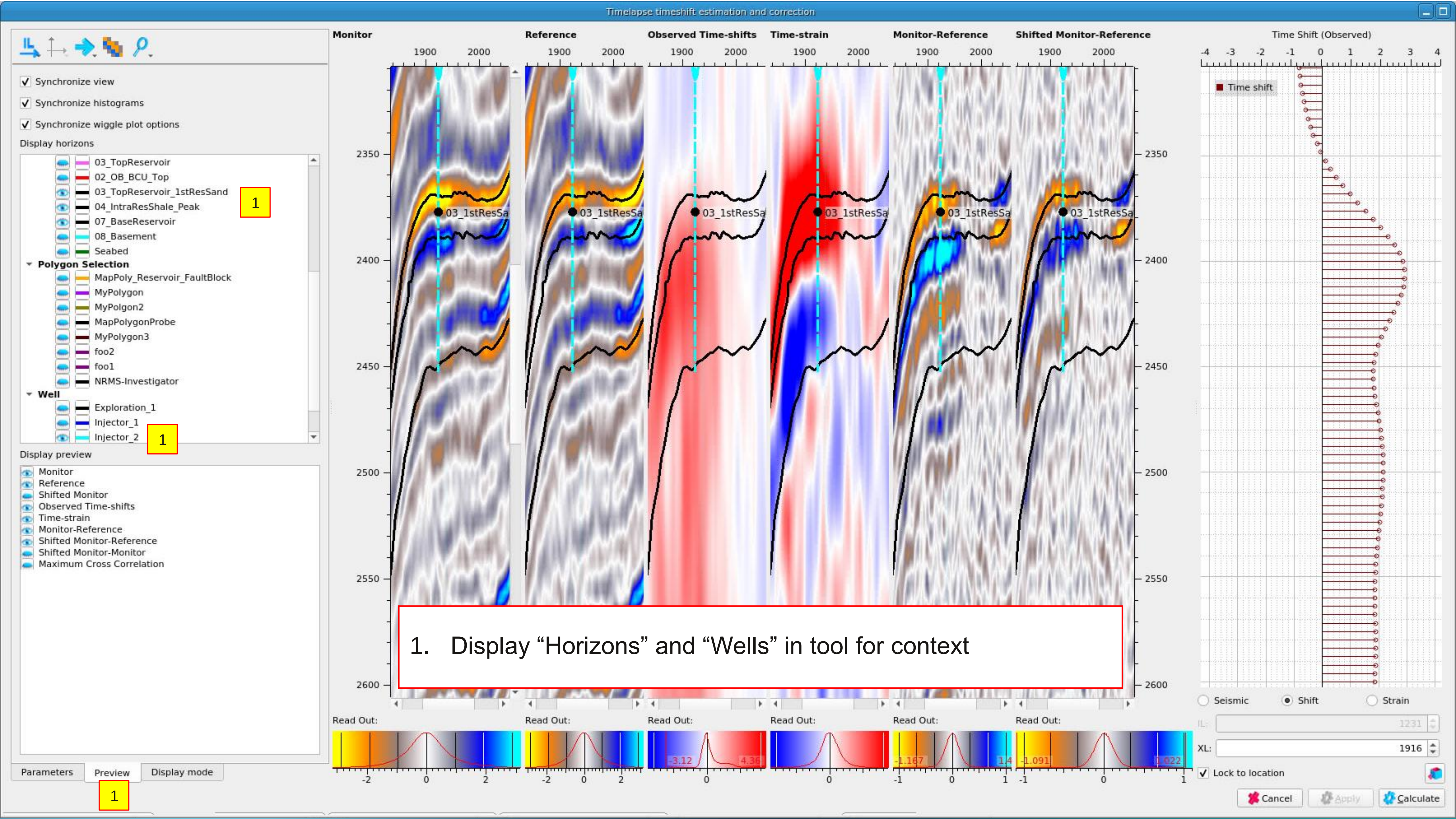


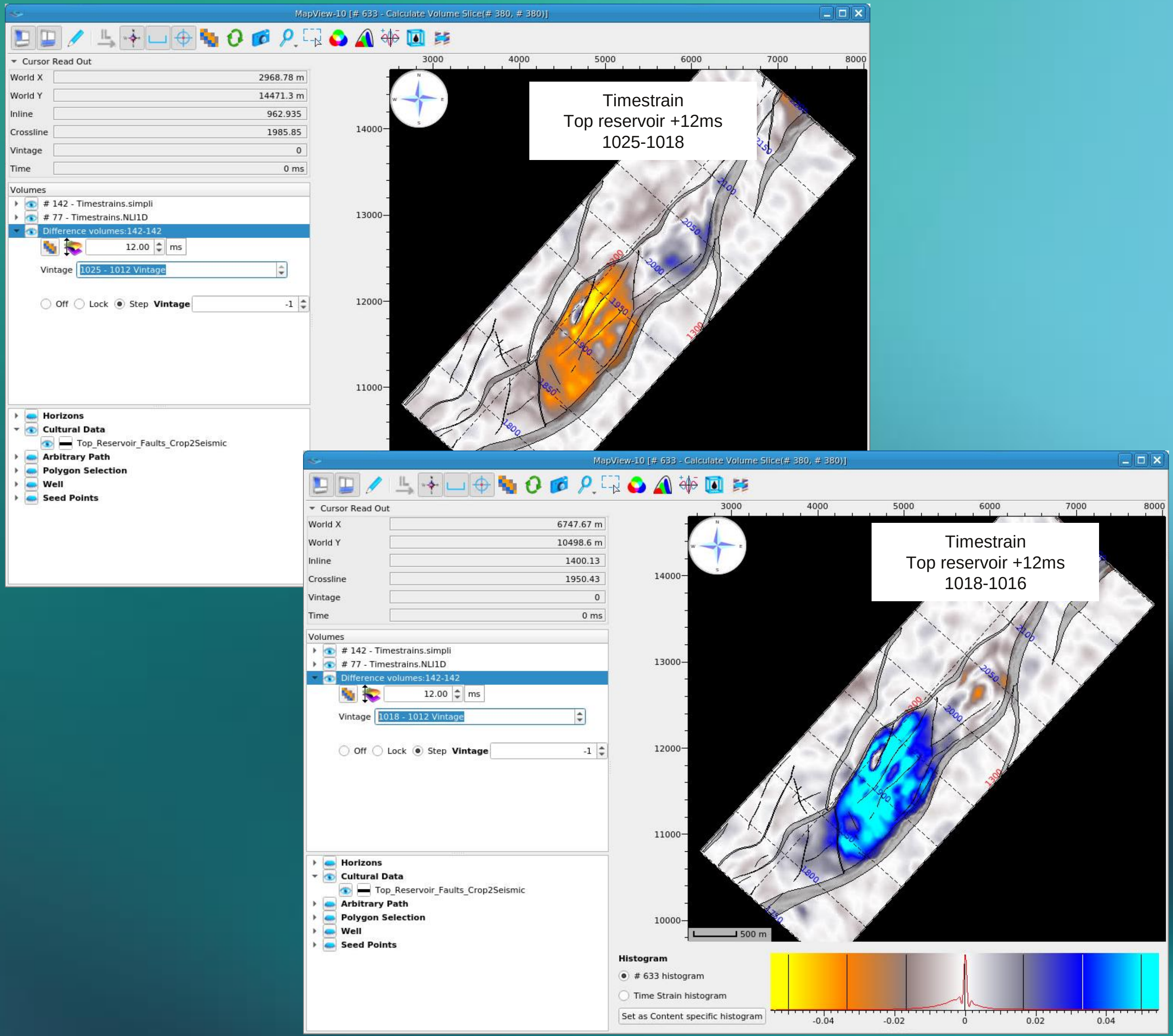
1. Display “Horizons” and “Wells” in tool for context

Timeshift estimation

(5) Timestrain maps as a 4D attribute

Learning goals:

- *Demonstrate the use of time-lapse timestrains as an interpretable 4D attribute*
- *Similar information content of timestrains and acoustic impedance change*



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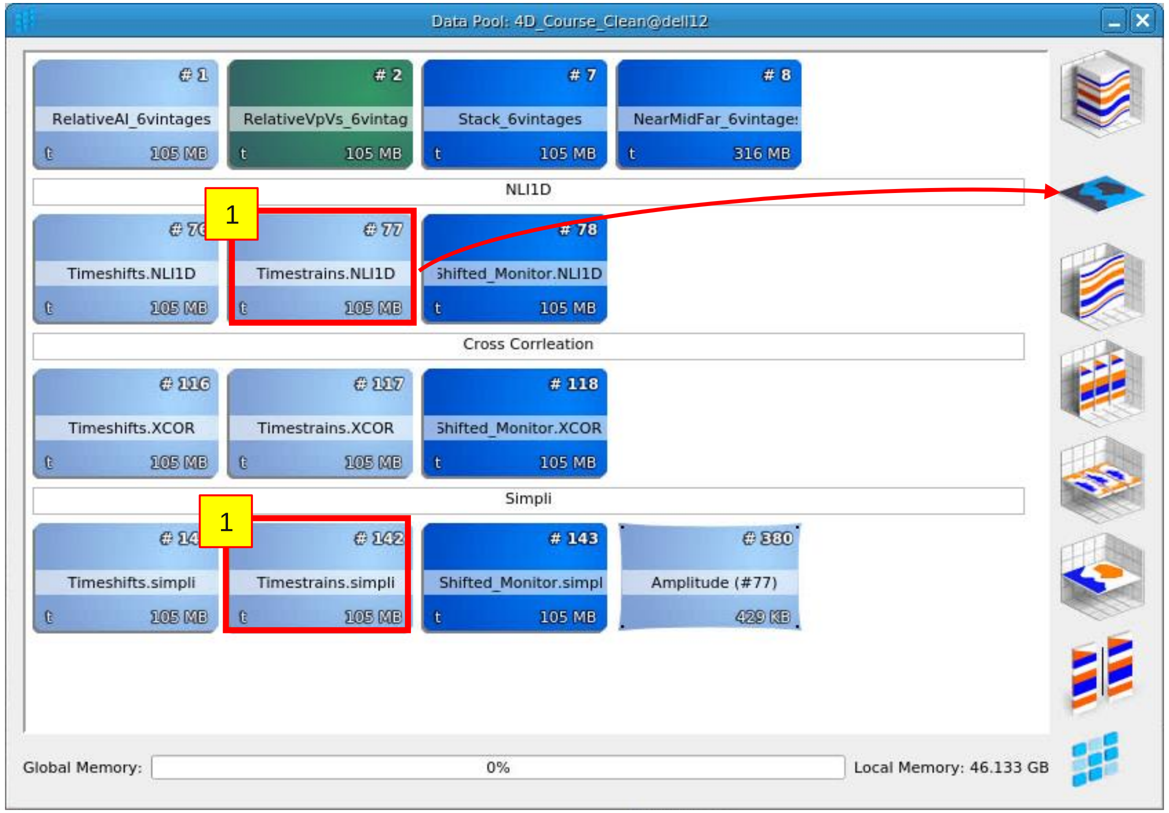
SHARP REFLECTIONS

Exercise 5

Timestrain maps as 4D attributes for interpretation



Investigate the use of timestrain as a 4D map attribute, and compare with acoustic impedance difference maps

1. Display your timestrains (using your favourite estimation method) in a "Map Viewer". Either drag-and-drop to Map-viewer icon, or
   Highlight items using Ctrl+LMB, then RMB into empty space in Data Pool, the "Show selected volumes in Map Viewer"

   Here I am using the timestrains from simpli and NLI1D

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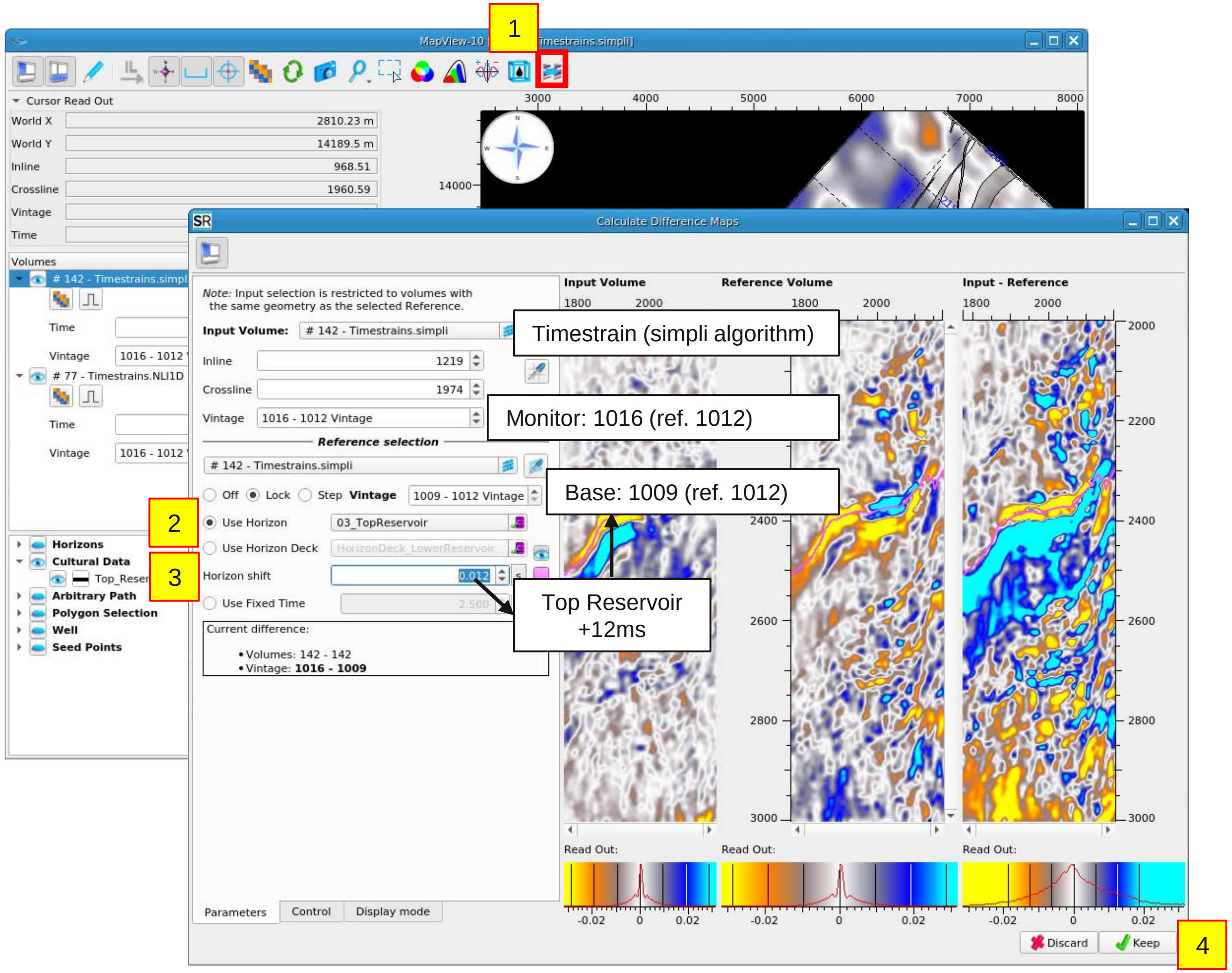
Timestrain maps as 4D attributes for interpretation



The Map Viewer shows by default a time slice.

Using the "difference-in-viewer" (1), difference maps on horizon can be calculated and displayed on the fly.

1. "Difference-in-viewer" opens a "Calculate Difference Map" window
2. Toggle on "Use Horizon" and select "03_TopReservoir"
3. Shift horizon downwards by 8 ms.
4. Press "Keep"

- Note the horizon display in the pre-view
- Note also the effect of controls in "Vintage" and selection for "Input Volume" (=Monitor) and "Reference Selection" (=Baseline). We will discuss these in detail in the next slide
- Horizon extractions can be done on several horizons simultaneously using "Horizon decks" instead of a single horizon

Alternatively, multi-vintage maps can be generated using "Interpretation-Processing"→"Create Maps" and "Interpretation-Processing"→"Create Interval Maps". These maps can then (also) be displayed in the Map Viewer

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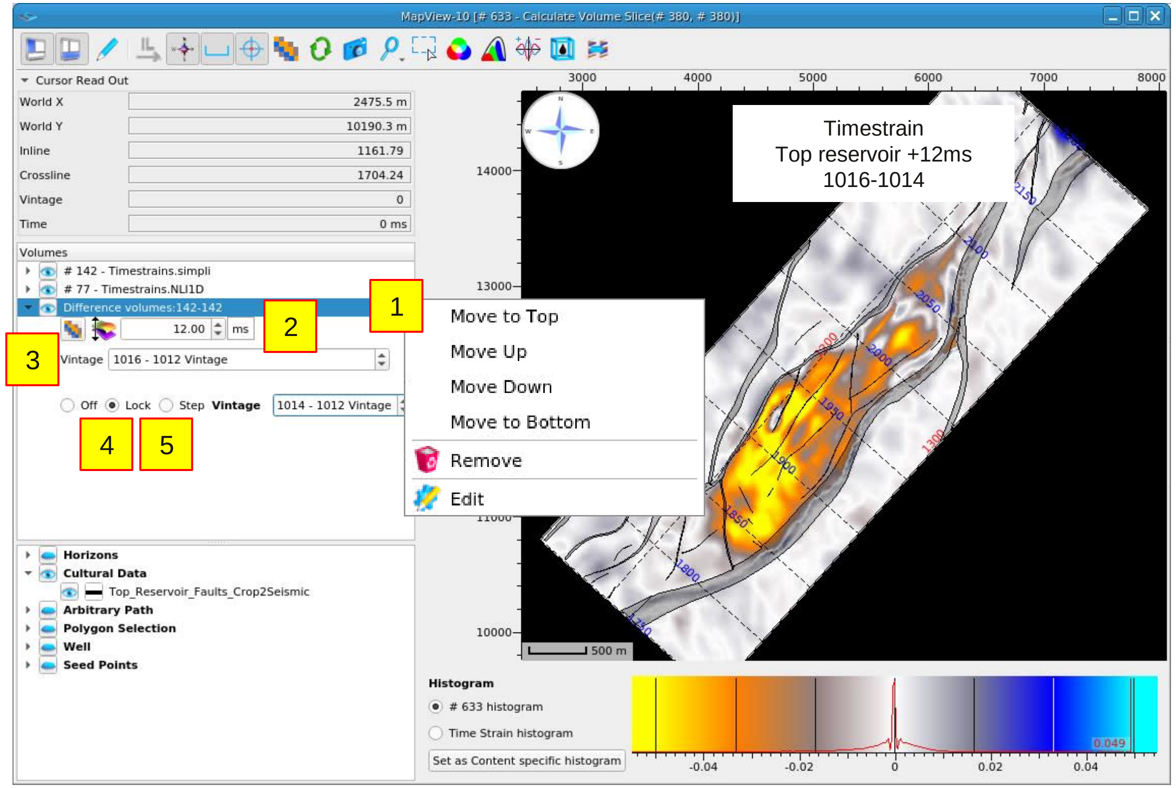
Timestrain maps as 4D attributes for interpretation



The “Map Viewer” now shows the 4D difference in time-strains

Spend some time to think about how to control the display, and how the vintage controls work

1. RMB on the selected difference volume, “Edit” brings back the “Calculate Difference Map” window
2. Control moving slice-horizon up/down
3. Monitor selection. On the left, Monitor volume is Timestrain 1016, with reference to 1012 (1016-1012)
4. Baseline selection: “Lock” sets the baseline to value shown in spin-box. Here Timestrain 1014, with reference to 1012. Therefore we are taking a double-difference: (1016-1012) - (1014-1012) = 1016-1014.
5. Baseline selection: “Step”. This creates step-wise diffrences with a step-size indicated in the spin-box. In the example, the Monitor selection (3) is timestrains in 1016 (with reference to 1012), using a step of -1, the baseline is timestrains in 1014 (with reference to 1012)

Hovering the mouse will show vintage difference

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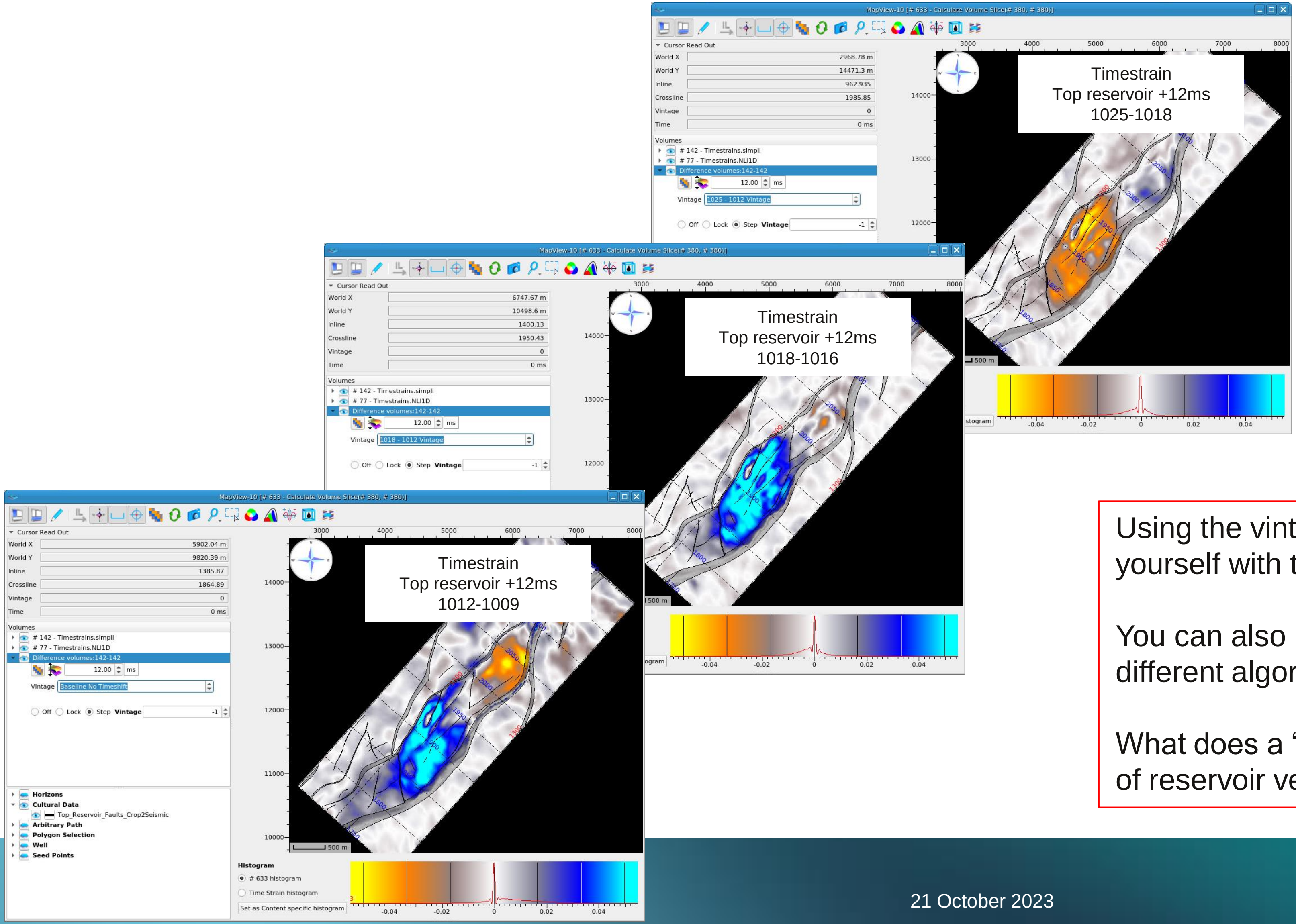
Timestrain maps as 4D attributes for interpretation

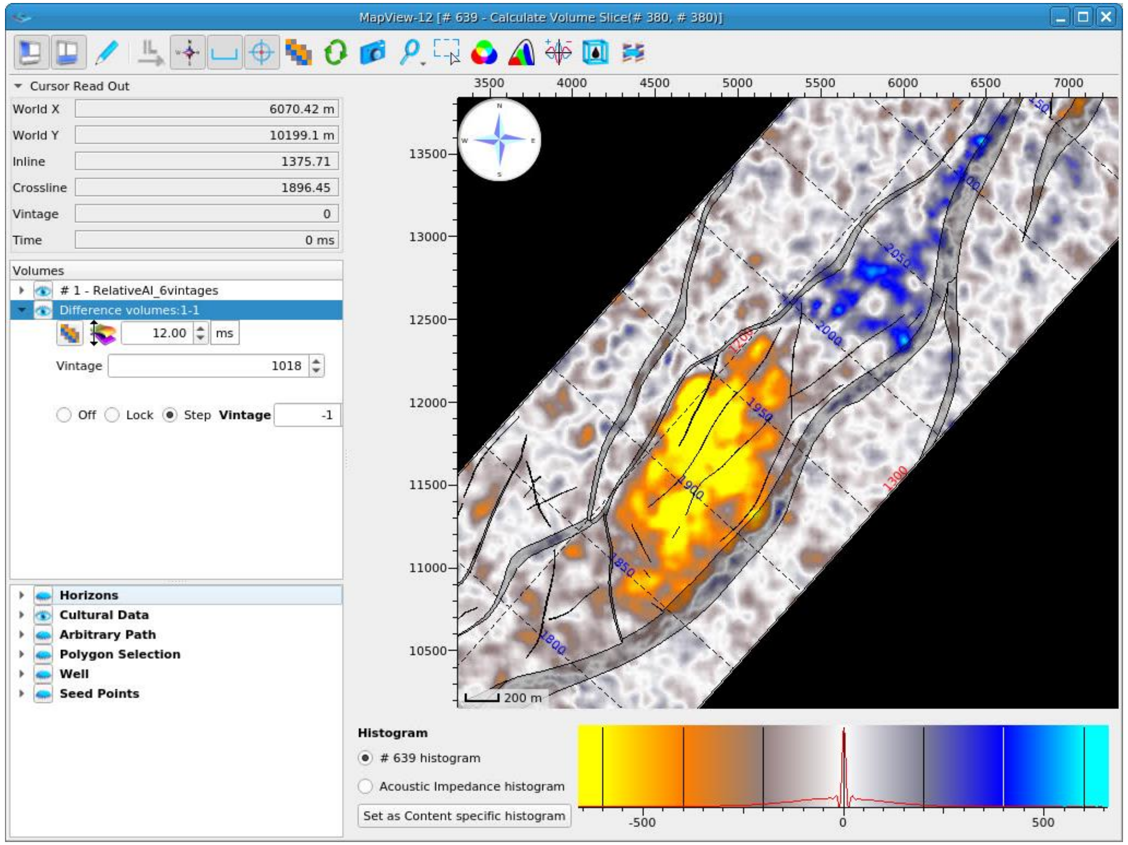


Using the vintage controls for baseline and monitor, familiarize yourself with the timestrain maps.

You can also repeat the exercise with timestrains calculated a different algorithm

What does a “positive” and “negative” timestrain mean in terms of reservoir velocity changes?

Comparison of 4D timestrain and 4D acoustic impedance differences



Repeat map creation using multi-vintage volume of Relative Acoustic Impedance Inversion volumes
File Manager: "Other → RelativeAI_6vintages"

You will find a strong anti-correlation between time-strain and ∆AI

- negative timestrain → positive acoustic impedance change, and vice versa,
- positive timestrain → negative acoustic impedance change

Why? If you are uncertain, have a look at the background material (p. 61 ff)

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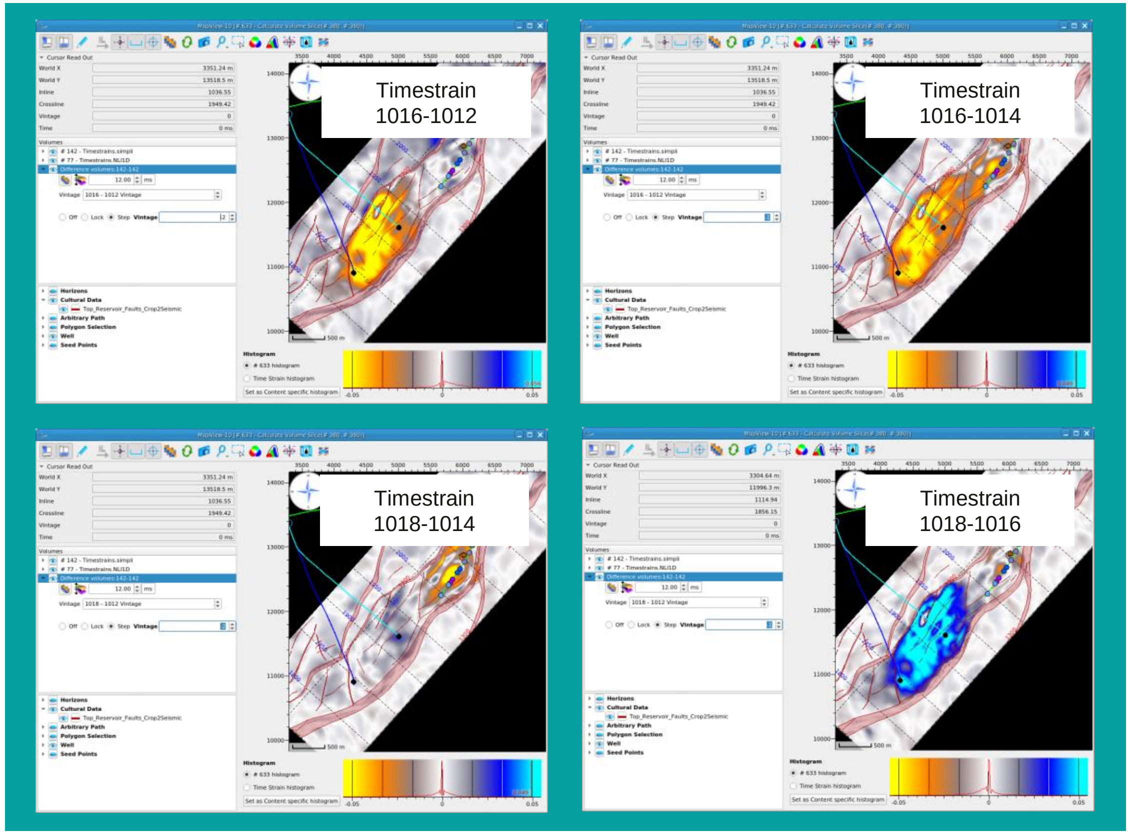
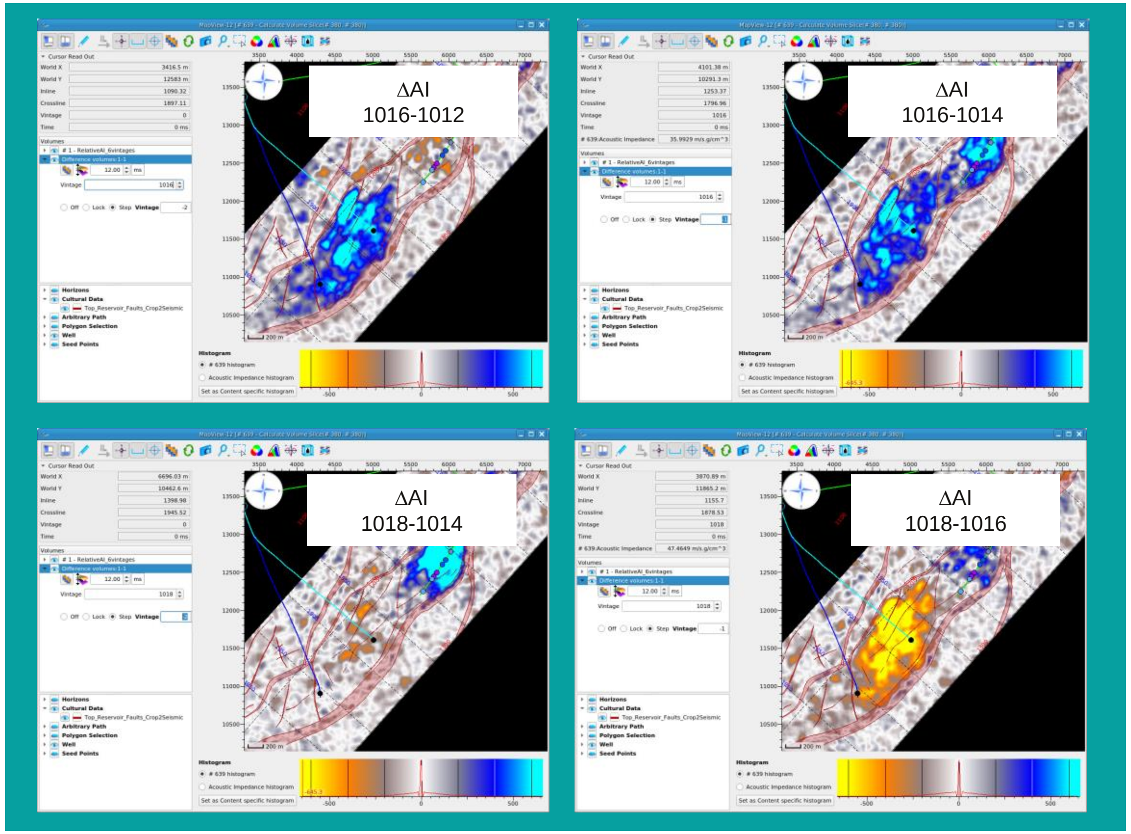
Comparison of 4D timestrain and 4D acoustic impedance differences

Timestrains



Acoustic impedance difference



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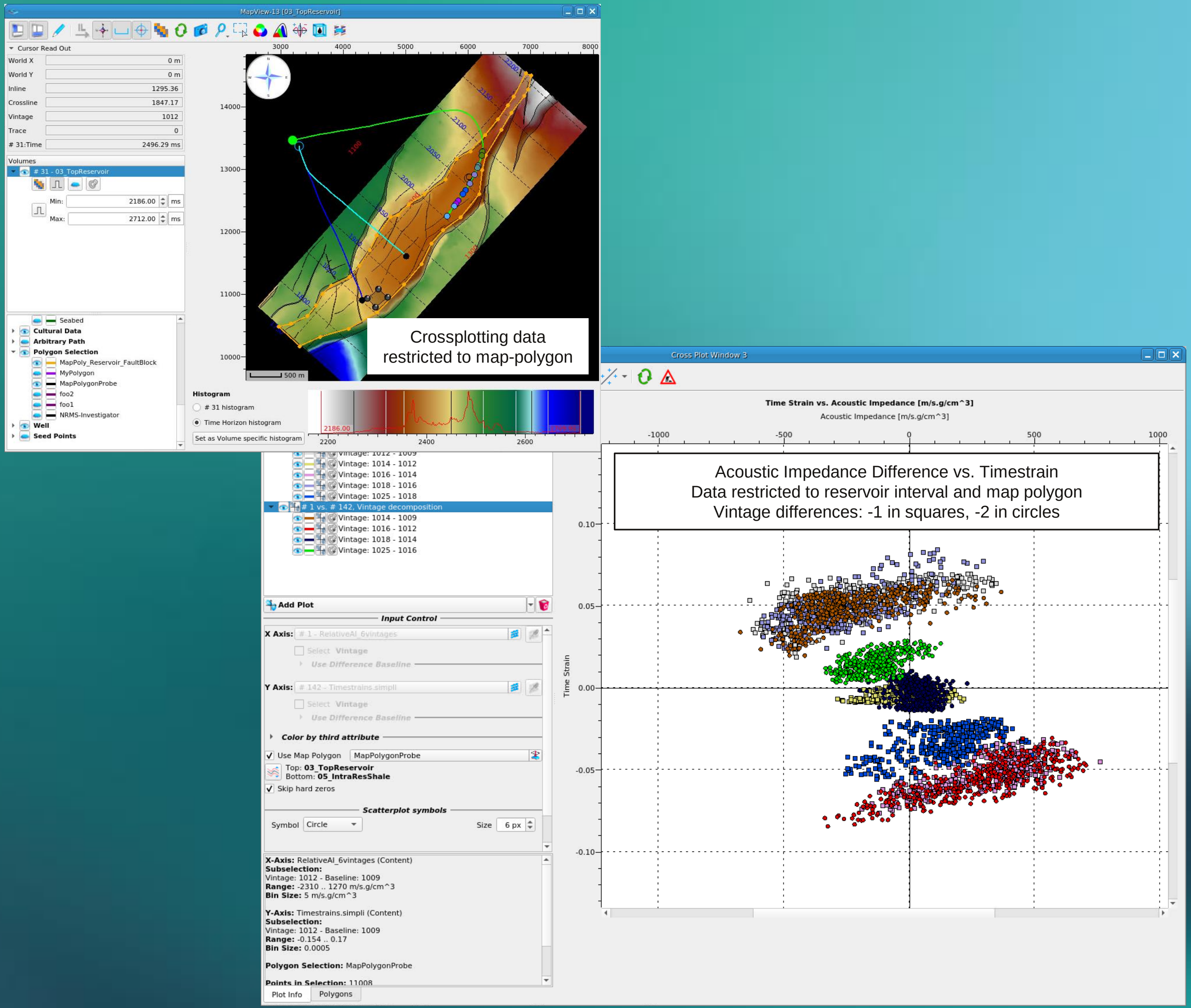
Timeshift estimation

(6) Crossplotting timestrains and acoustic impedance differences

Learning goals:

- *Another use of the cross-plotting tool*
- *Showing the anti-correlation of time-strains and acoustic impedance changes (ΔAI)*



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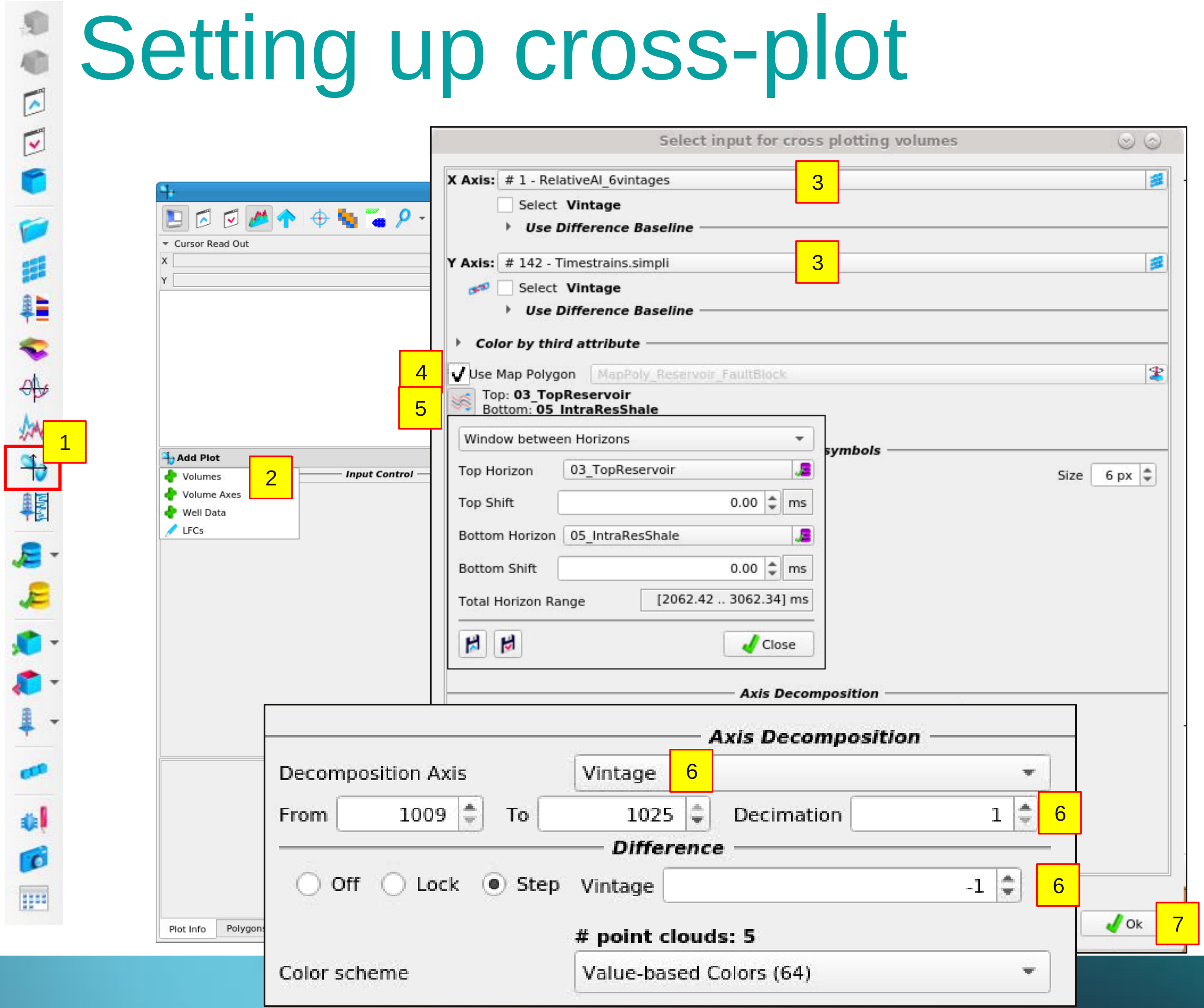
Setting up cross-plot



Starting and setting up the cross-plotter.

Load multi-vintage Timestrains and Relative Acoustic Impedance Inversion volume to data-pool

1. Double-click to open cross-plotter window
2. “Add Plot” → “Volumes” to open control window
3. “RelativeAI_6vintages” on x-axis
   “Timestrains.simpli” on y-axis
4. Restrict data to a polygon by enabling “Use Map Polygon”, and choose “MapPolygonProbe”
5. Extract data from volumes between horizons (or at shifted horizon)
   - Here extract data in reservoir interval bounded by “03_TopReservoir” and “05_IntraResShale”
6. Extract subvolumes from multi-vintage data by “Axis Decomposition”
   - Decompose the “Vintage” axis
   - Use all vintages
   - Use sequential differences
7. “Ok”

In principle, the data extracted between top- and bottom-reservoir should appear. In practice, we may have to coax the data to plot … more on this on the next slide. This is a pre-release version of the software, and under construction.

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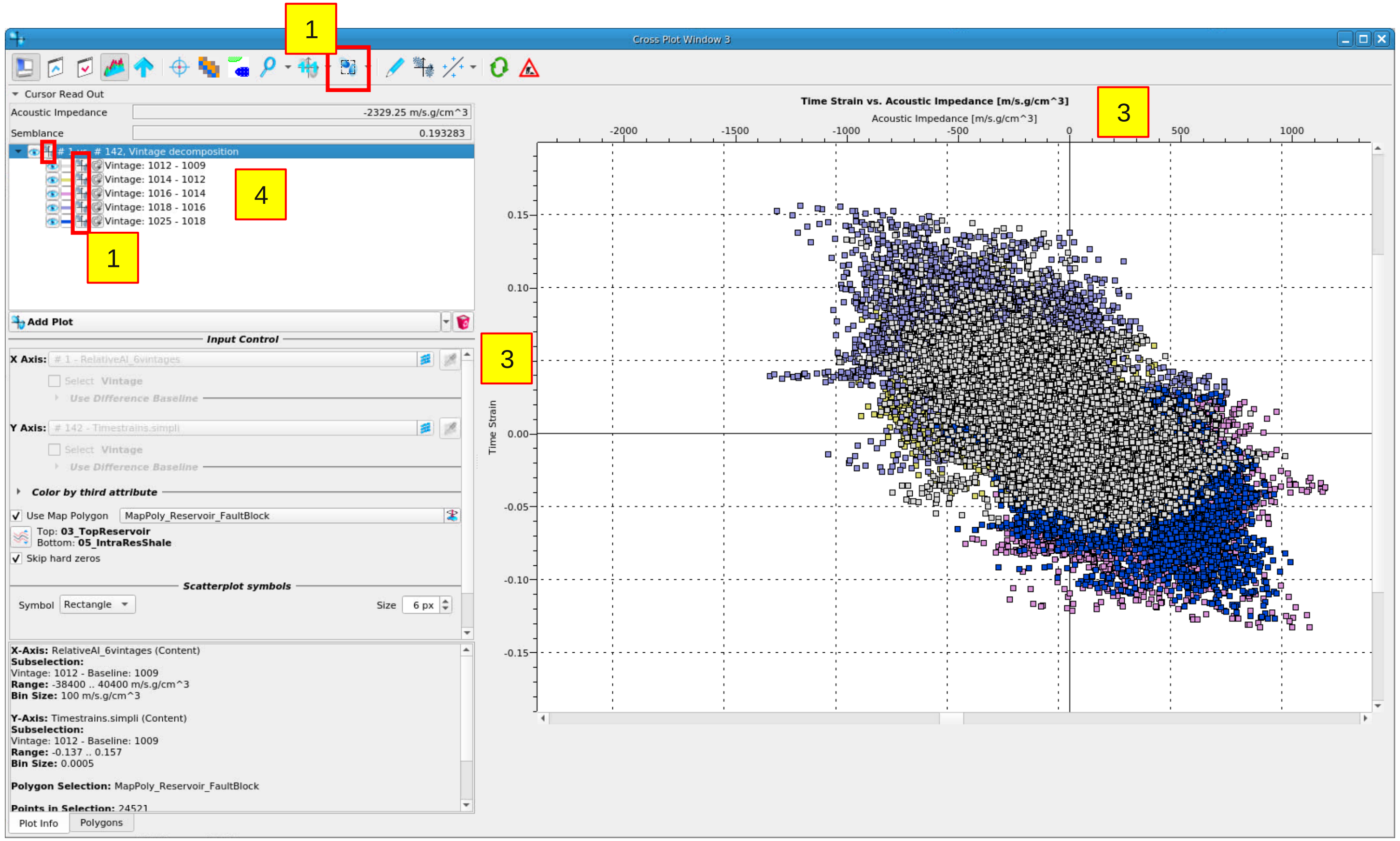
Setting up cross-plot: Controls



Start exploring the data

If data does not appear … try

1. Setting the toggling from “density display” to “discrete points”
2. “Recalculate points”
3. Zoom x- and y-axes (hover mouse over axis, and use scroll wheel on MMB)

Data will appear …

4. Highlight subset of the multi-vintage dataset (click, or use up/down keys) to bring to front

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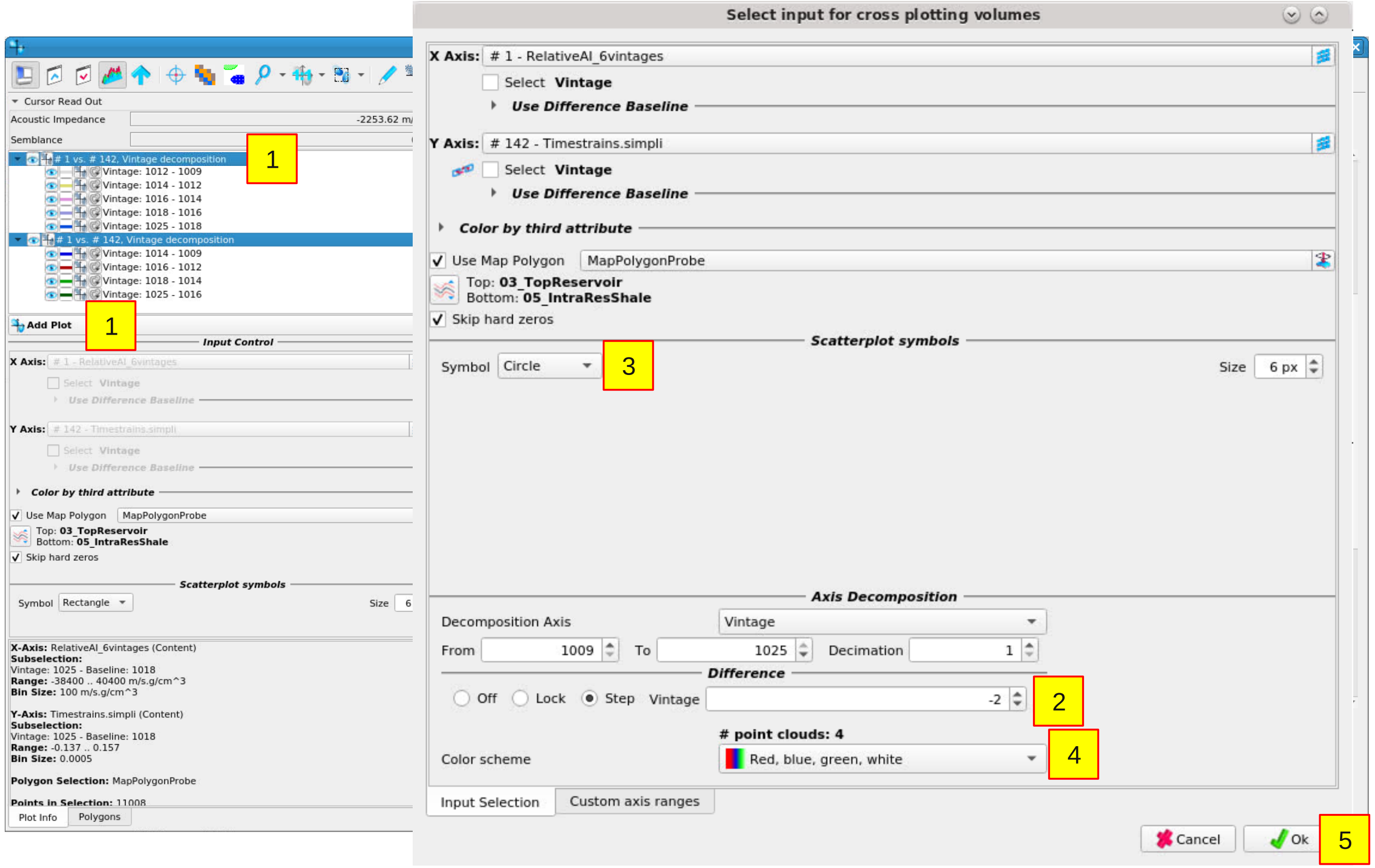
Setting up cross-plot: Adding more data



Add more data

1. Highlight top level data and "Add plot".
   - Note, that the "Input selector" shows the inputs used previously for the top level data
   - If a lower level data had been used, this data-set would be the basis of creating an additional dataset to the plot
2. Use a Vintage difference of -2 (Vintage differences of 2)
3. Use circles to depict data
4. Choose a new color-scheme
5. "Ok"

New data will plot … if not all data plots, press re-calculate.

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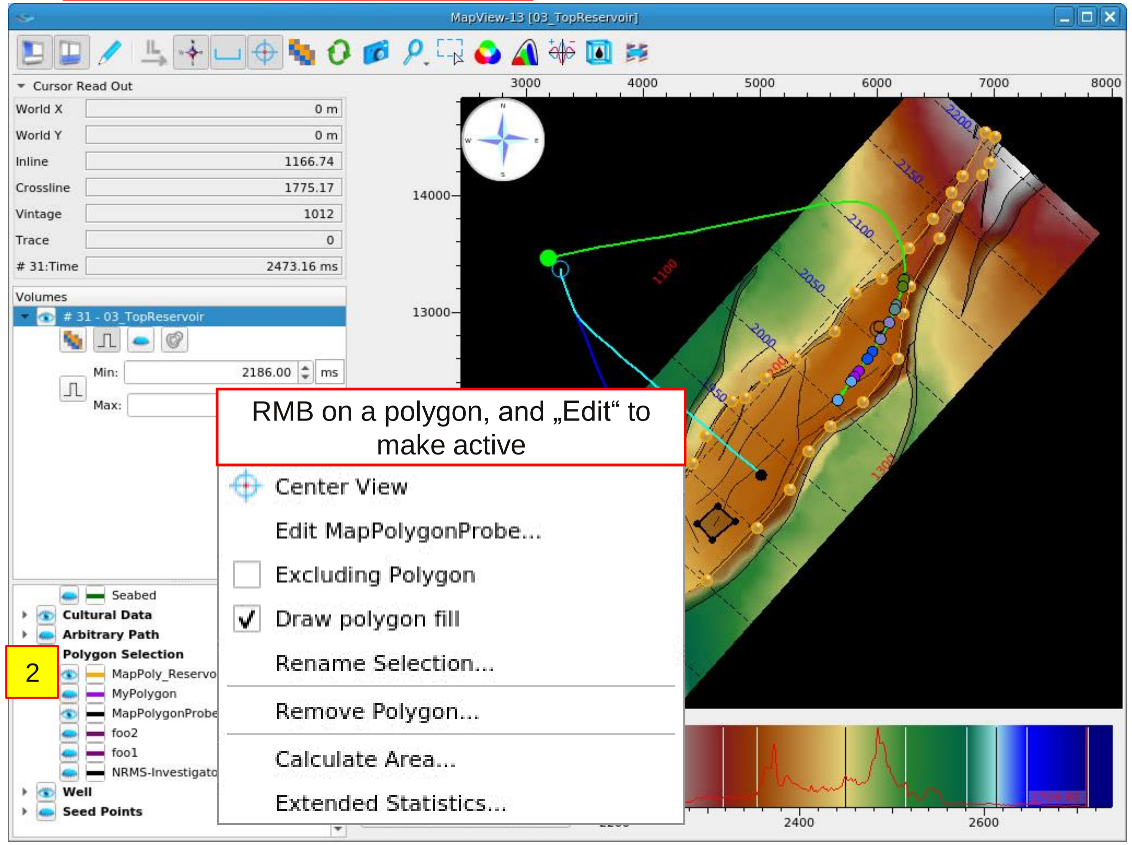
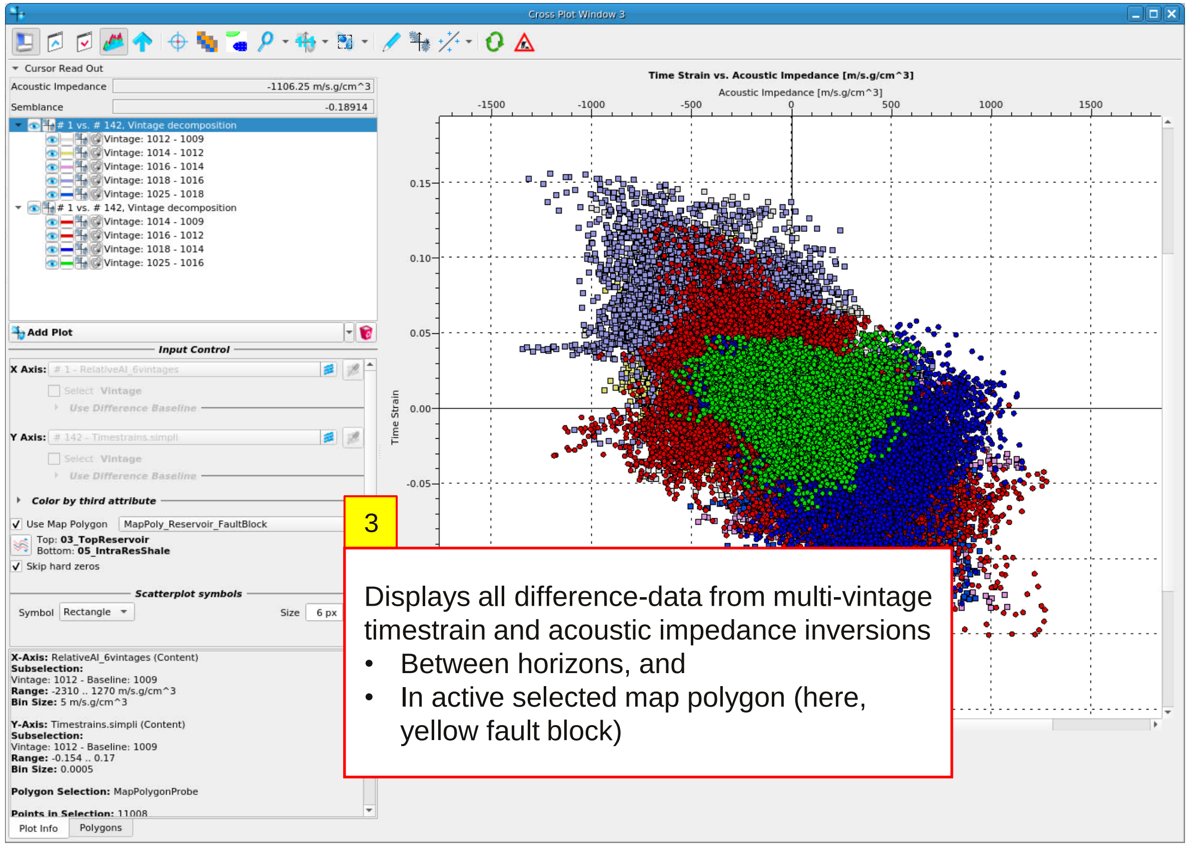
Explore crossplot

1 Open „Map Viewer“ and display top reservoir horizon



RMB on a polygon, and „Edit“ to make active

2



3

Displays all difference-data from multi-vintage timestrain and acoustic impedance inversions

- Between horizons, and
- In active selected map polygon (here, yellow fault block)

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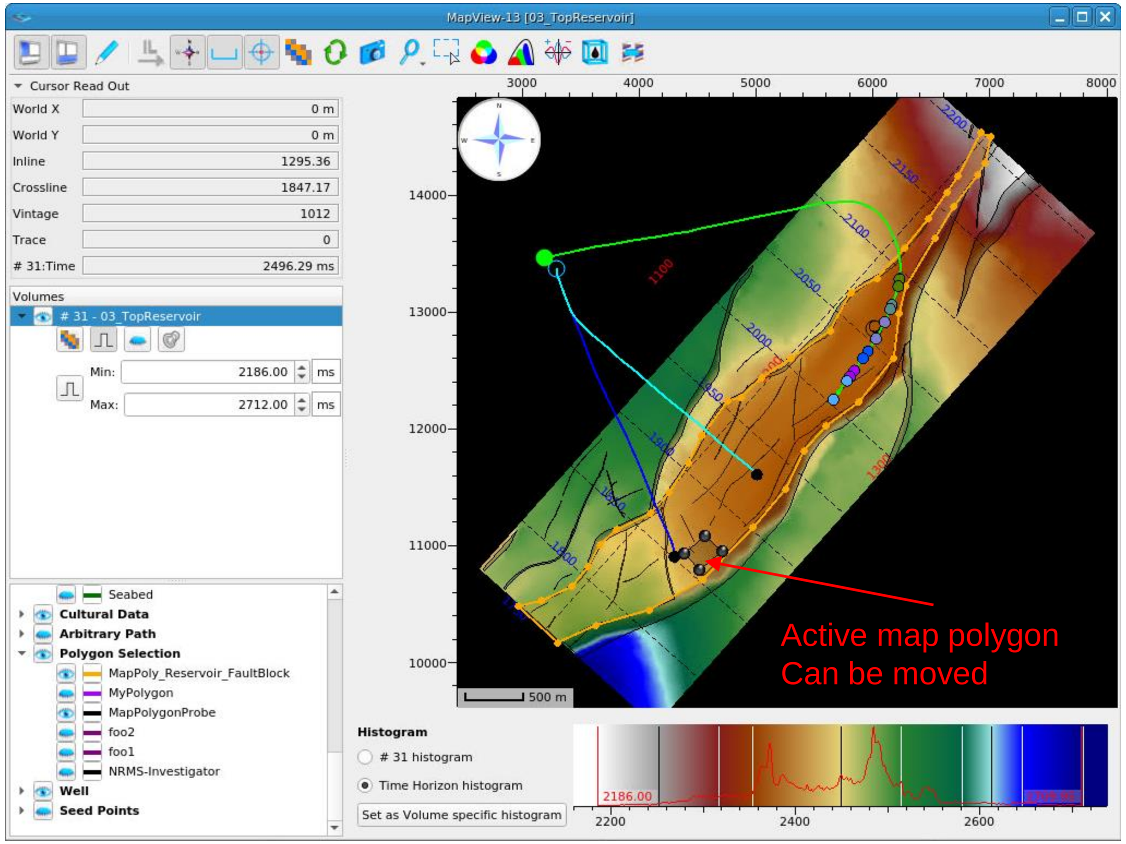
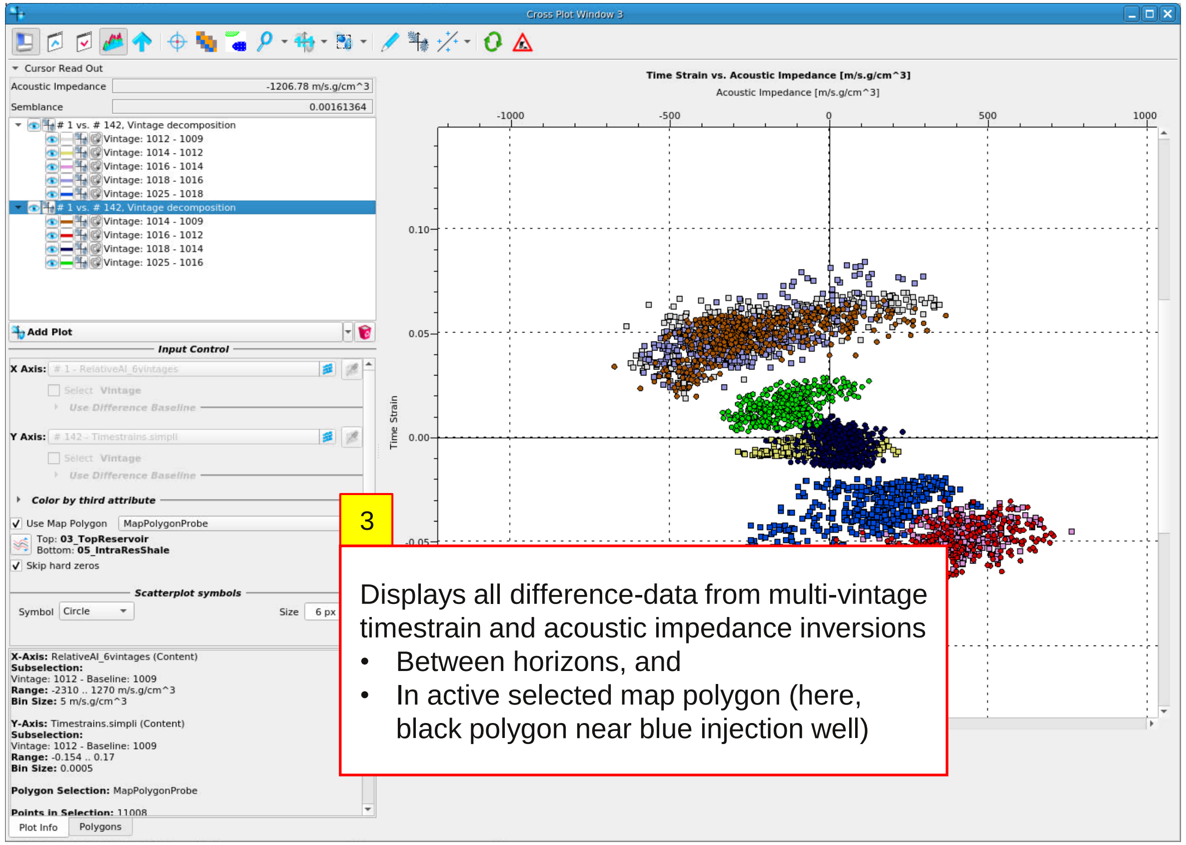
Exercise 6

Explore crossplot





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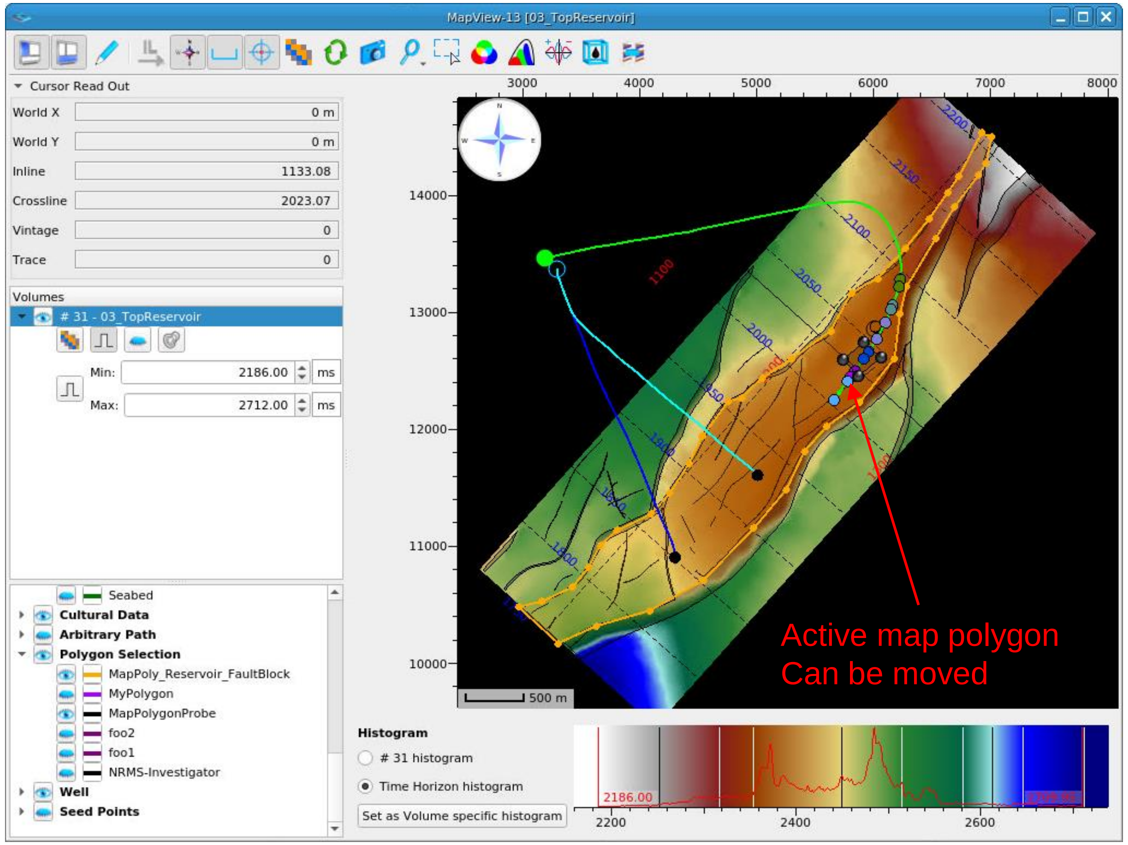
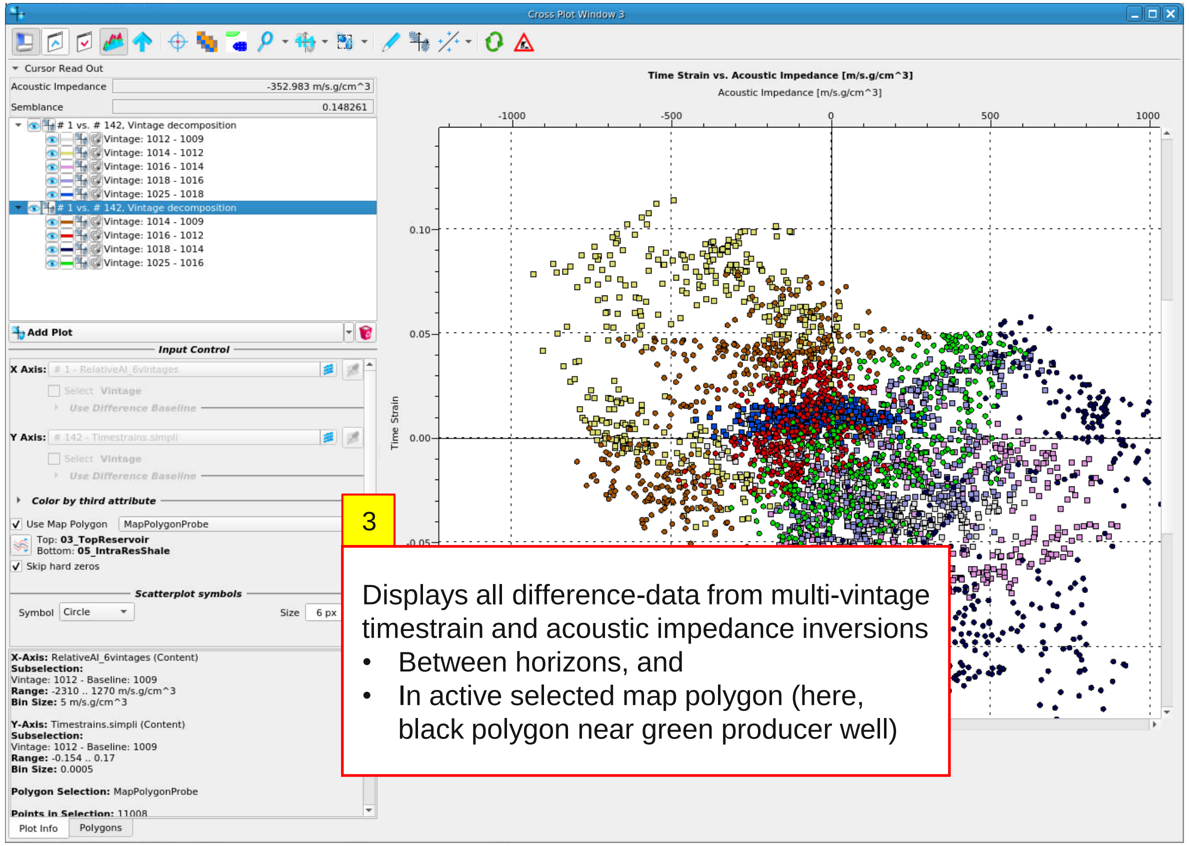
Explore crossplot





3

Displays all difference-data from multi-vintage timestrain and acoustic impedance inversions

- Between horizons, and
- In active selected map polygon (here, black polygon near green producer well)

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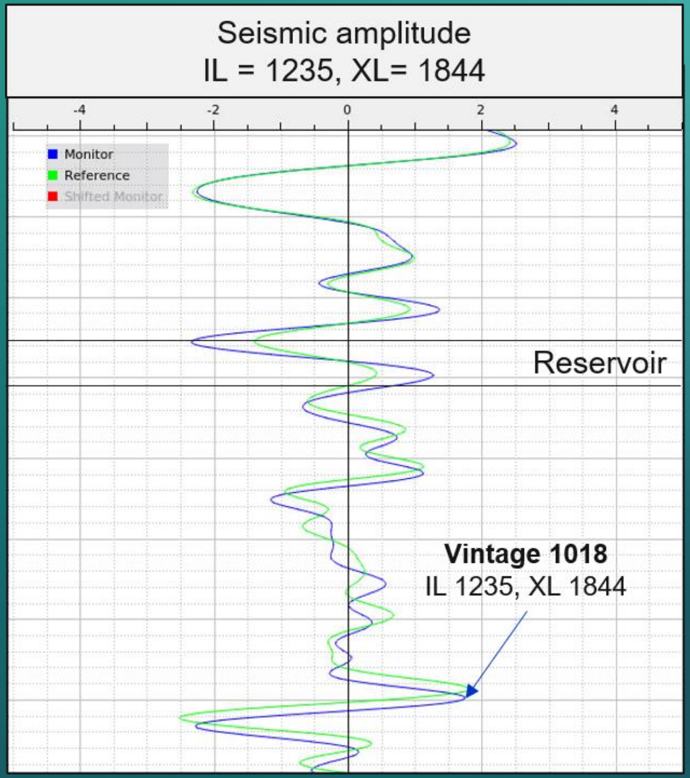
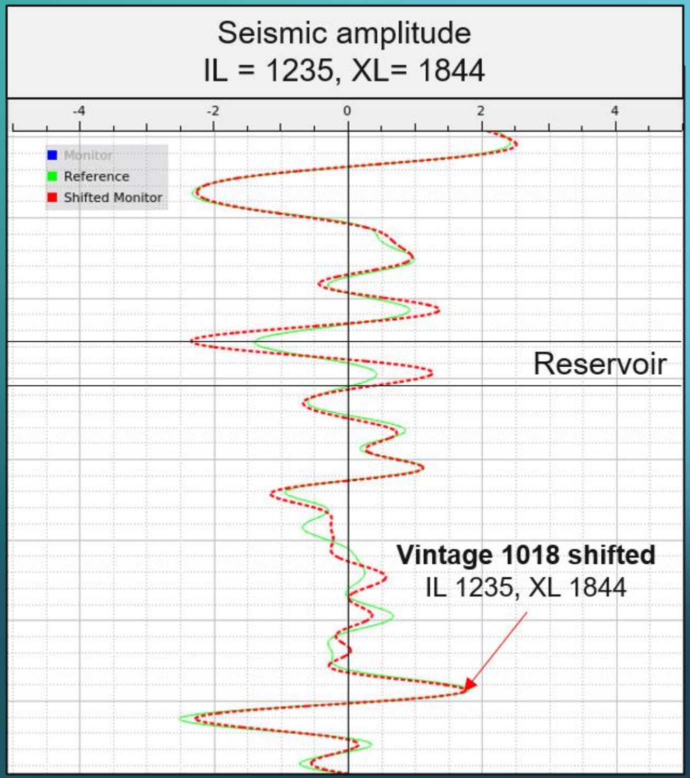
Timeshift estimation

Background

- *Causes of production-induced timeshifts*
- *Estimation and correction of time-lapse timeshifts*
- *Interpretation of time-lapse timeshifts*





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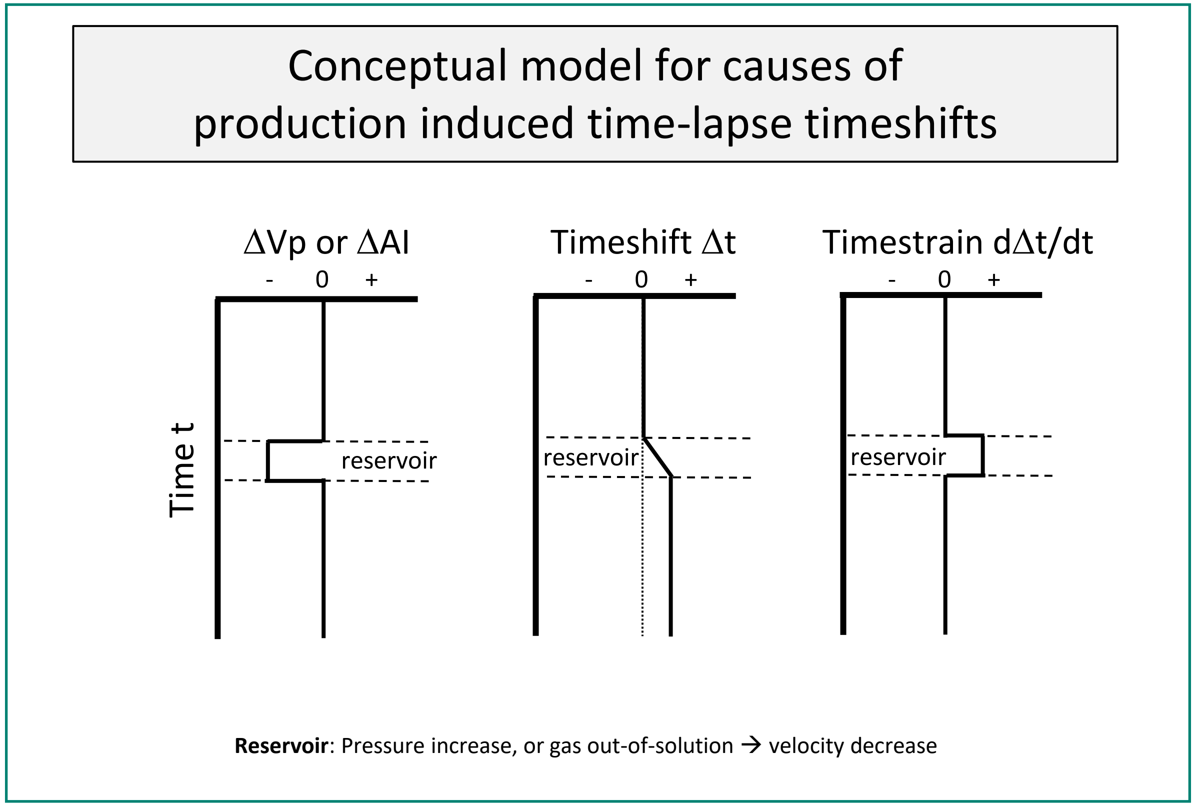
Causes of production induced time-lapse timeshifts



-ve ΔAI or ΔVp: Softening
→ +ve Timestrain

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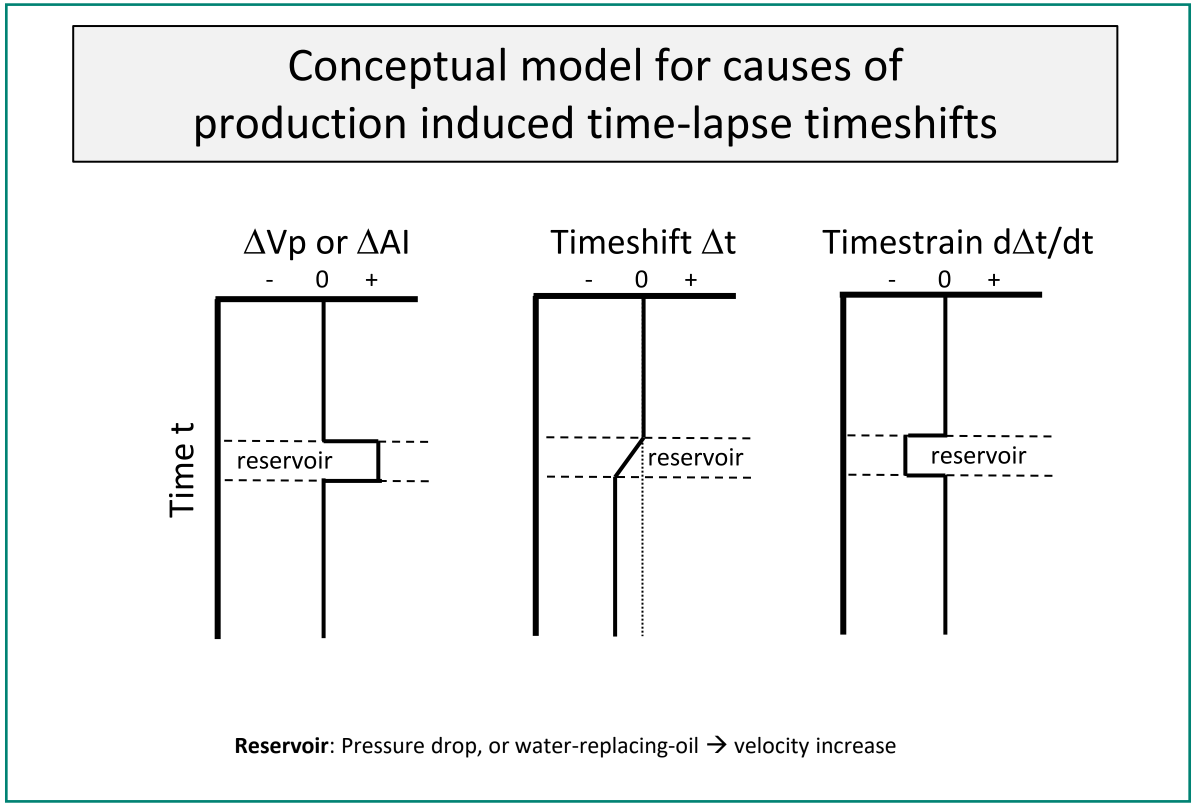
Causes of production induced time-lapse timeshifts



+ve ΔAI or ΔVp: Softening
→ -ve Timestrain

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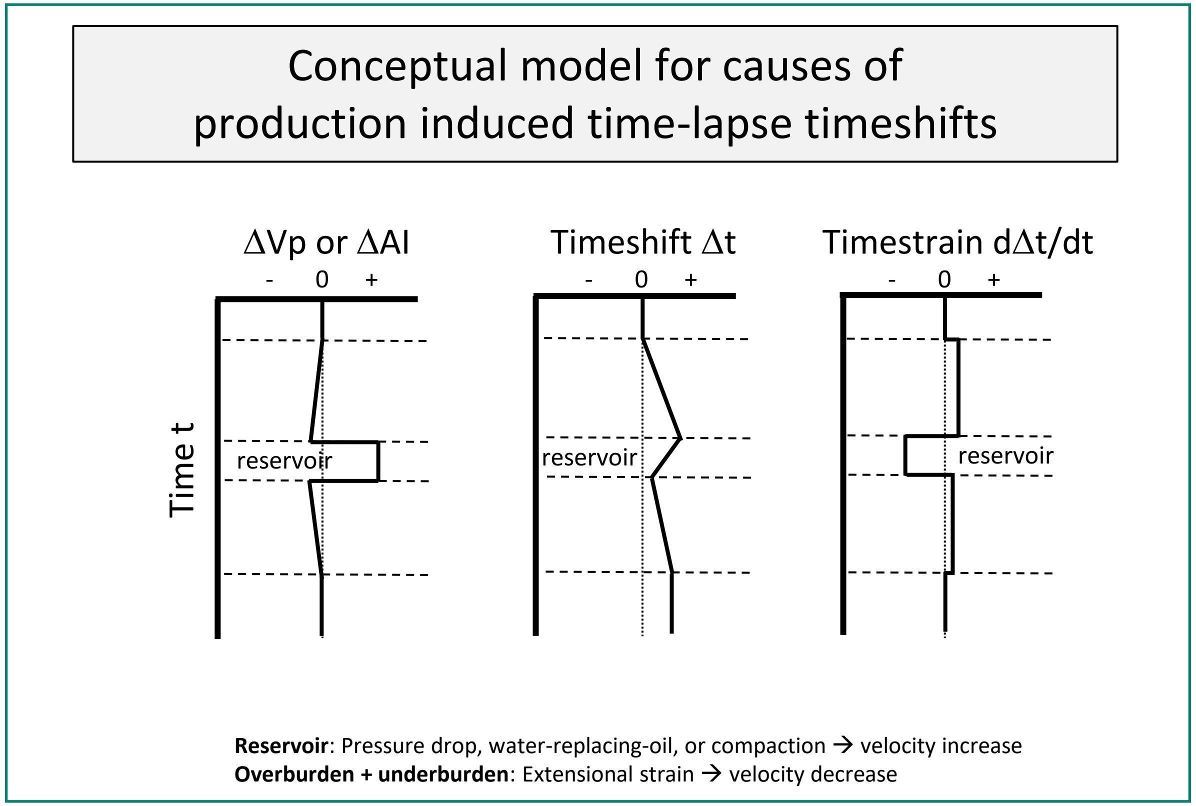
Causes of production induced time-lapse timeshifts



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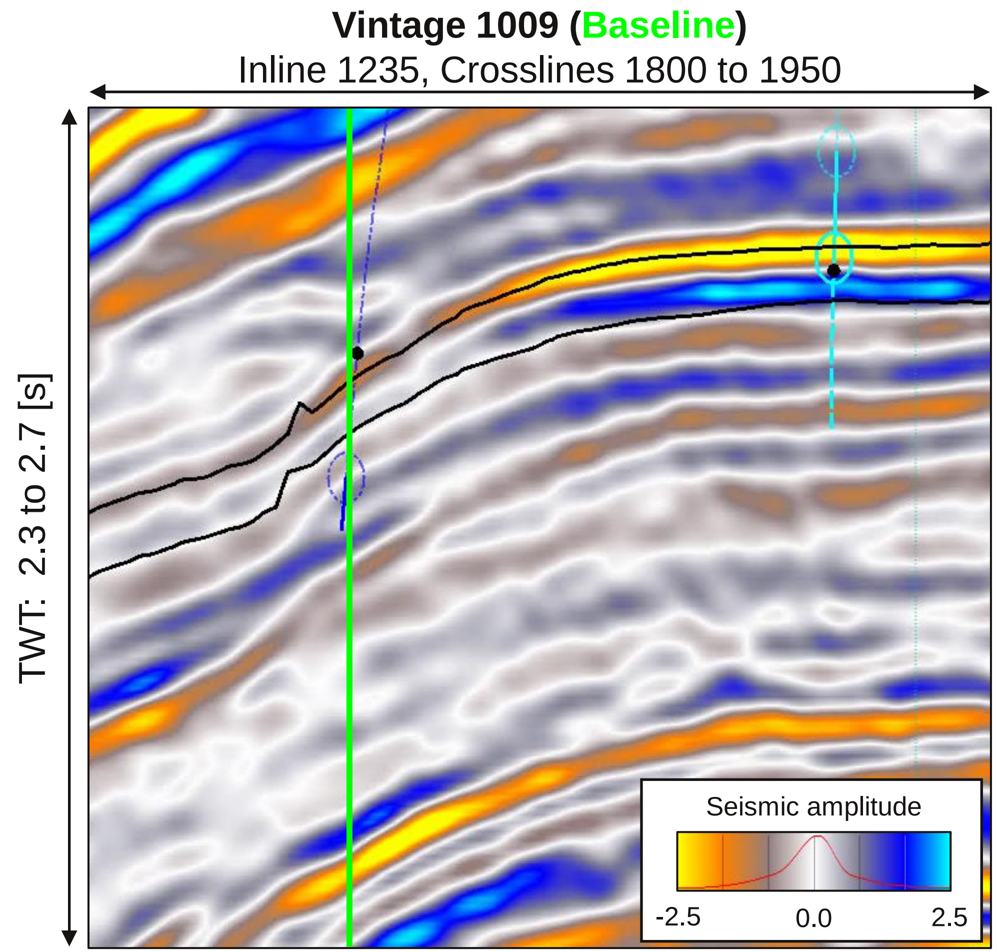
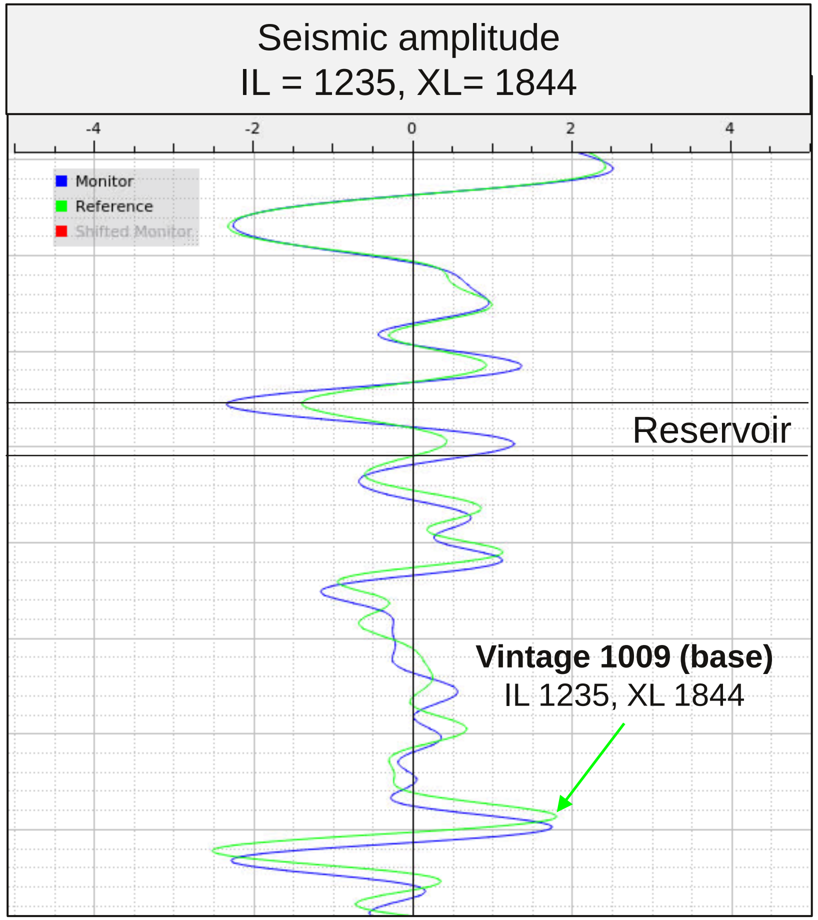
Correction of time-lapse timeshifts and 4D amplitude differences





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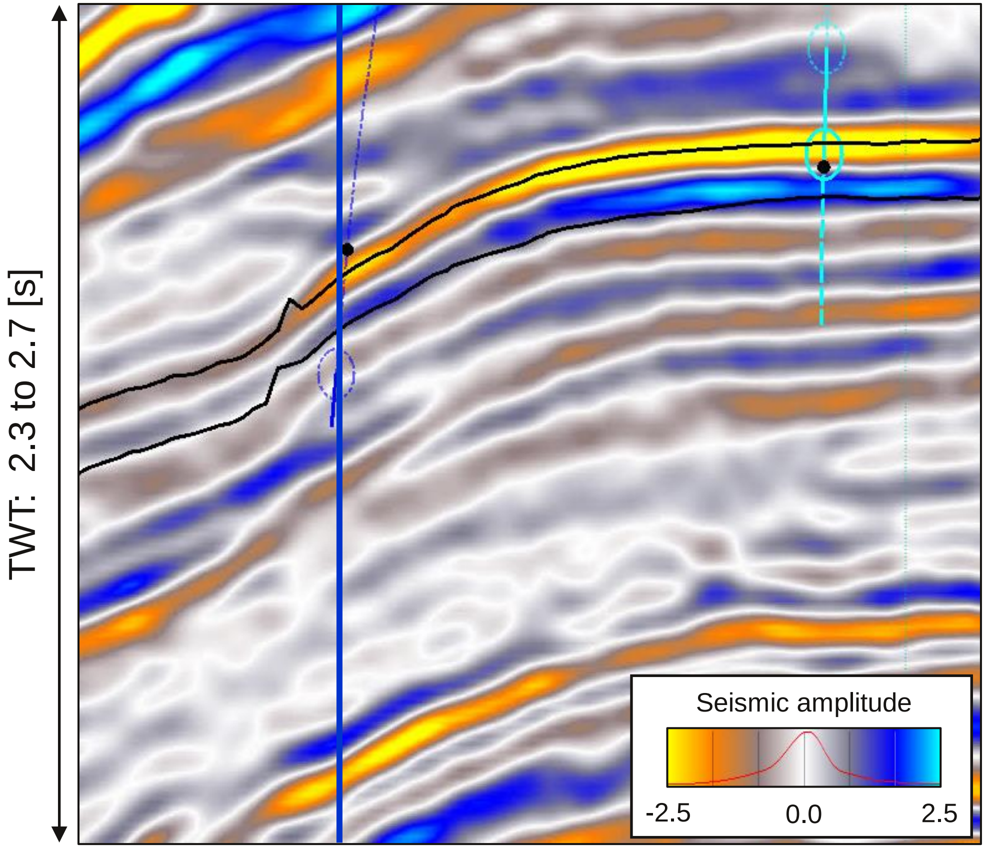
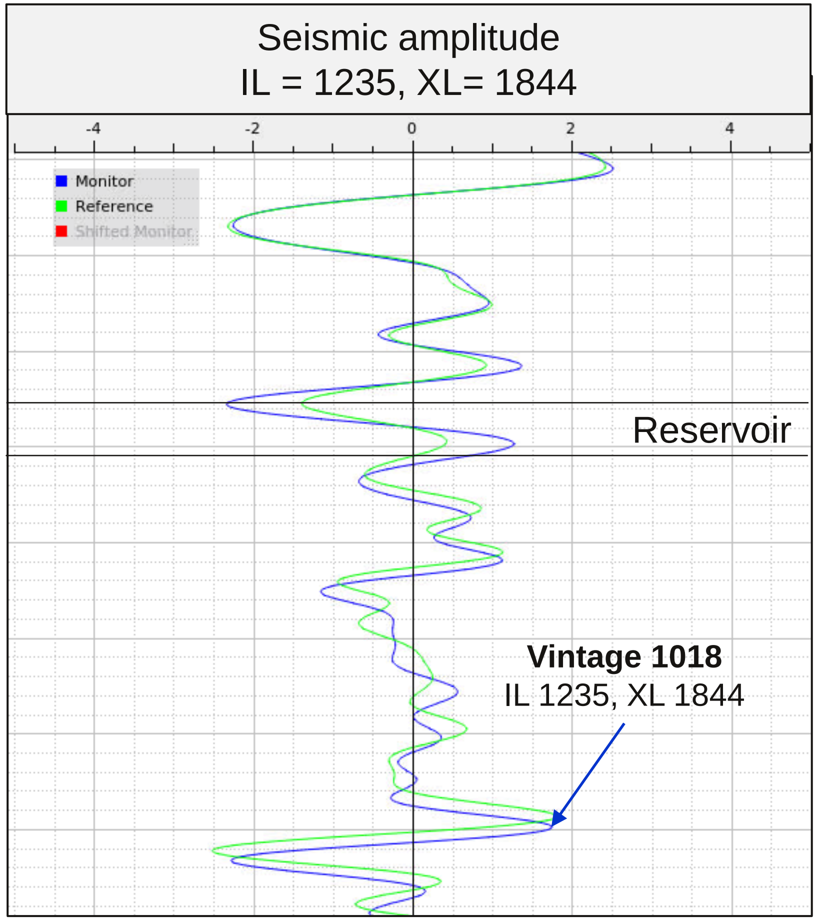
Correction of time-lapse timeshifts and 4D amplitude differences

Vintage 1018 (Monitor)
Inline 1235, Crosslines 1800 to 1950





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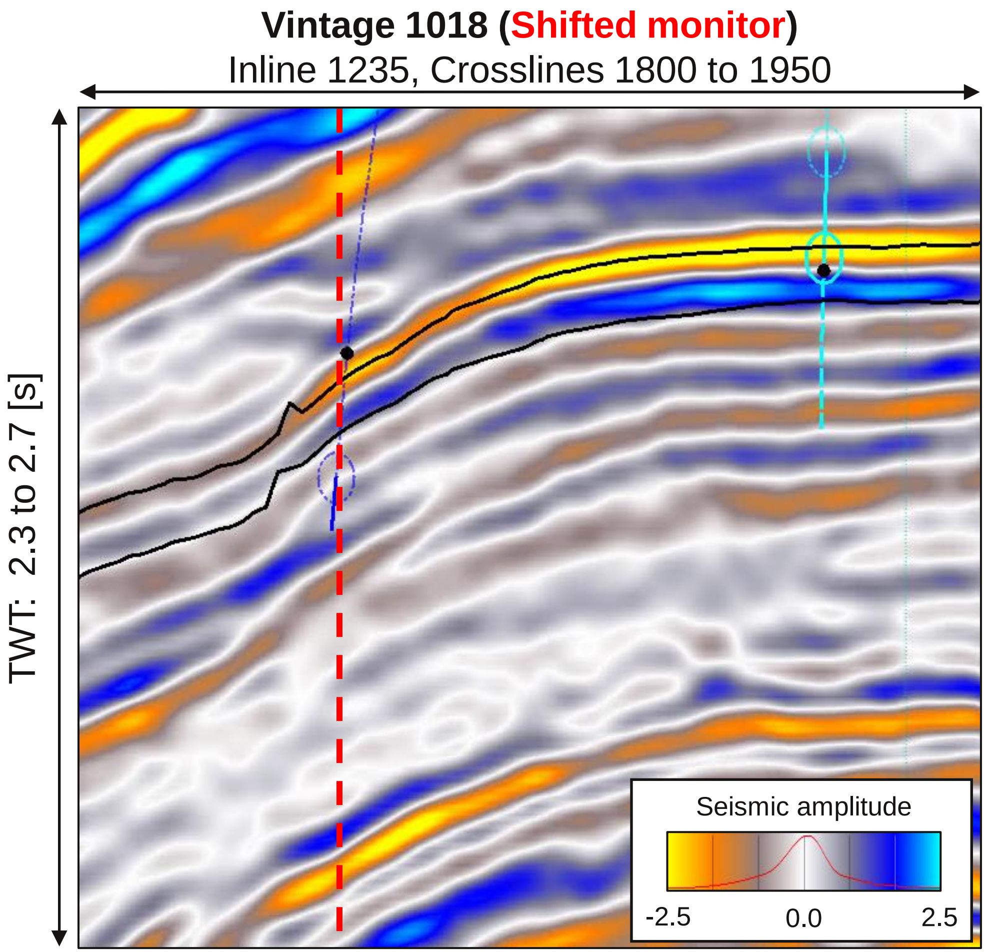
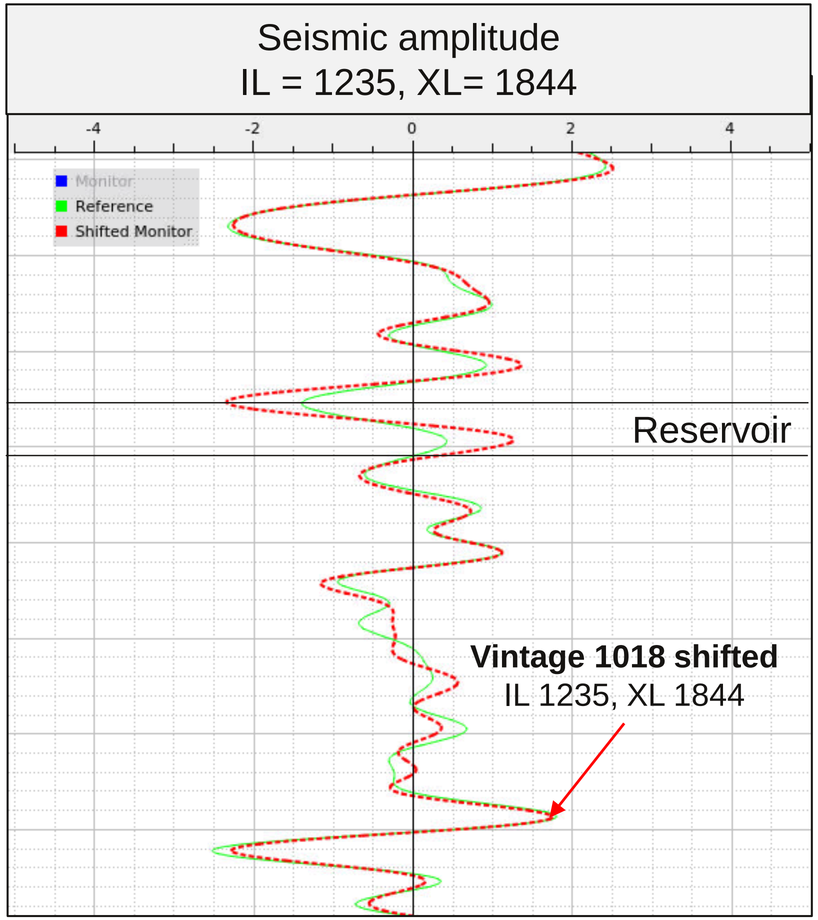
Correction of time-lapse timeshifts and 4D amplitude differences





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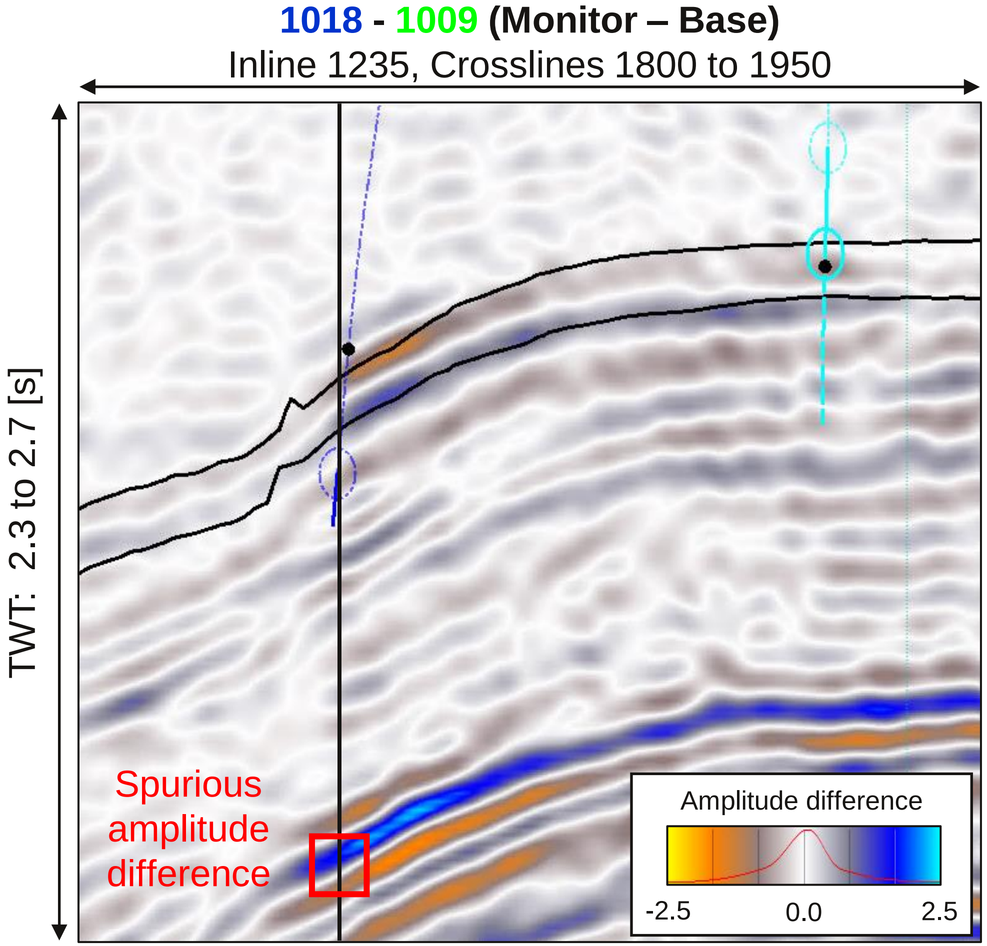
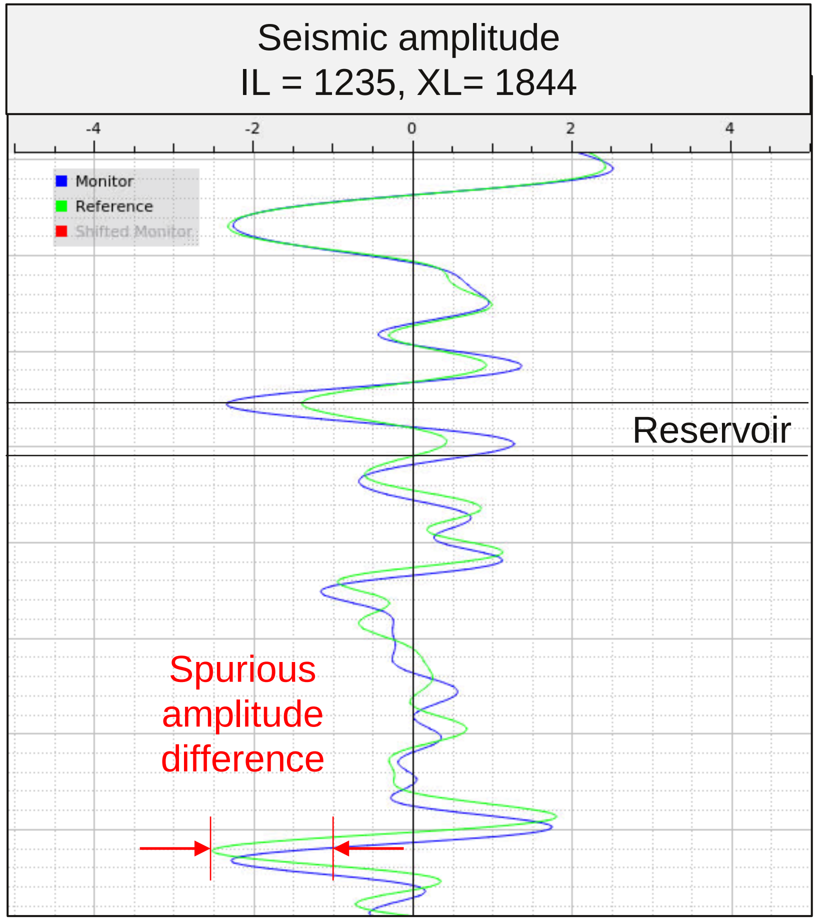
Correction of time-lapse timeshifts and 4D amplitude differences





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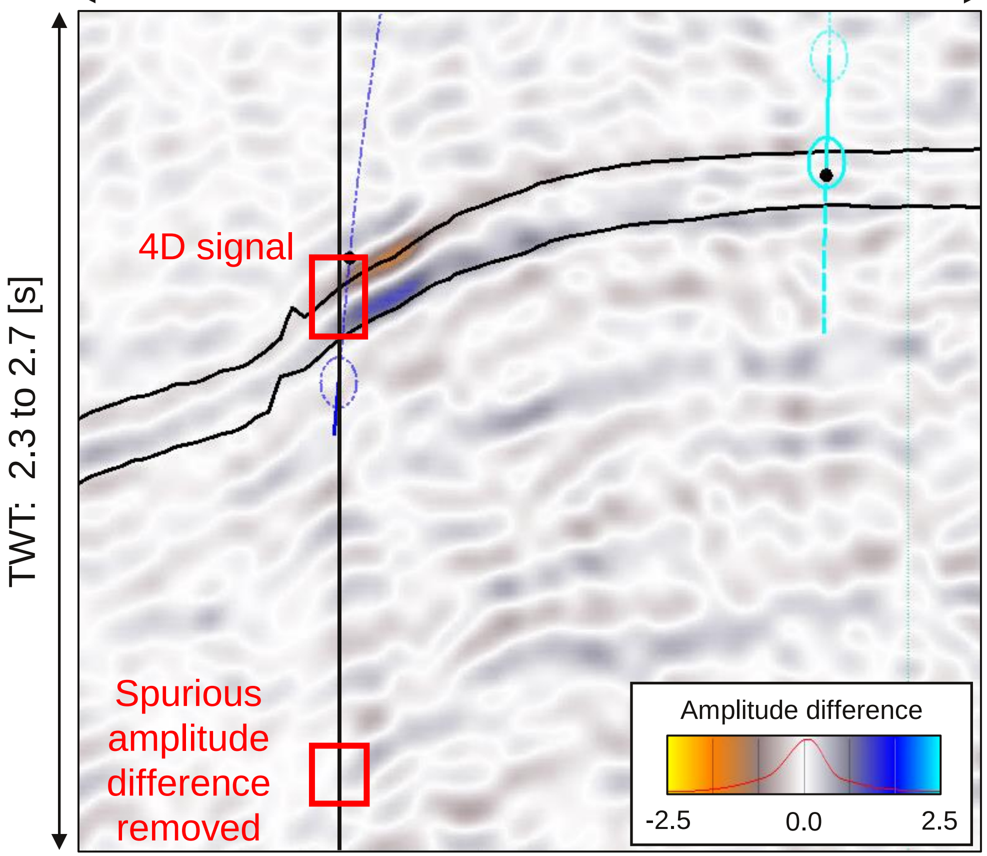
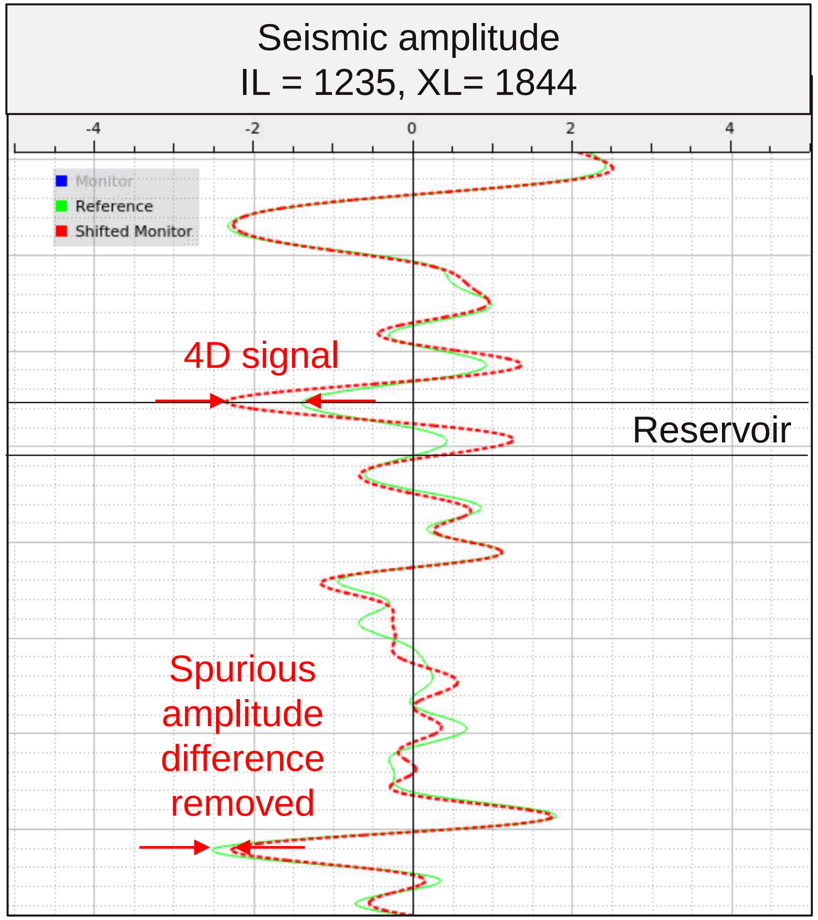
Correction of time-lapse timeshifts and 4D amplitude differences

Shifted 1018 - 1009 (Shifted monitor – Base)
Inline 1235, Crosslines 1800 to 1950





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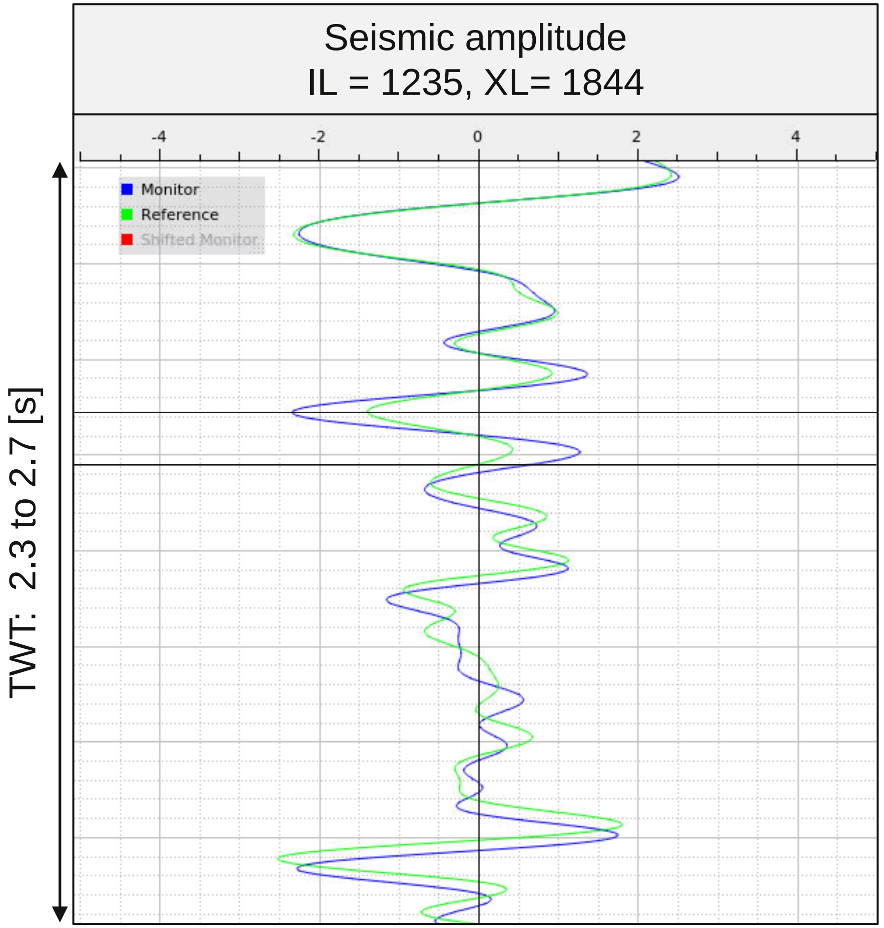
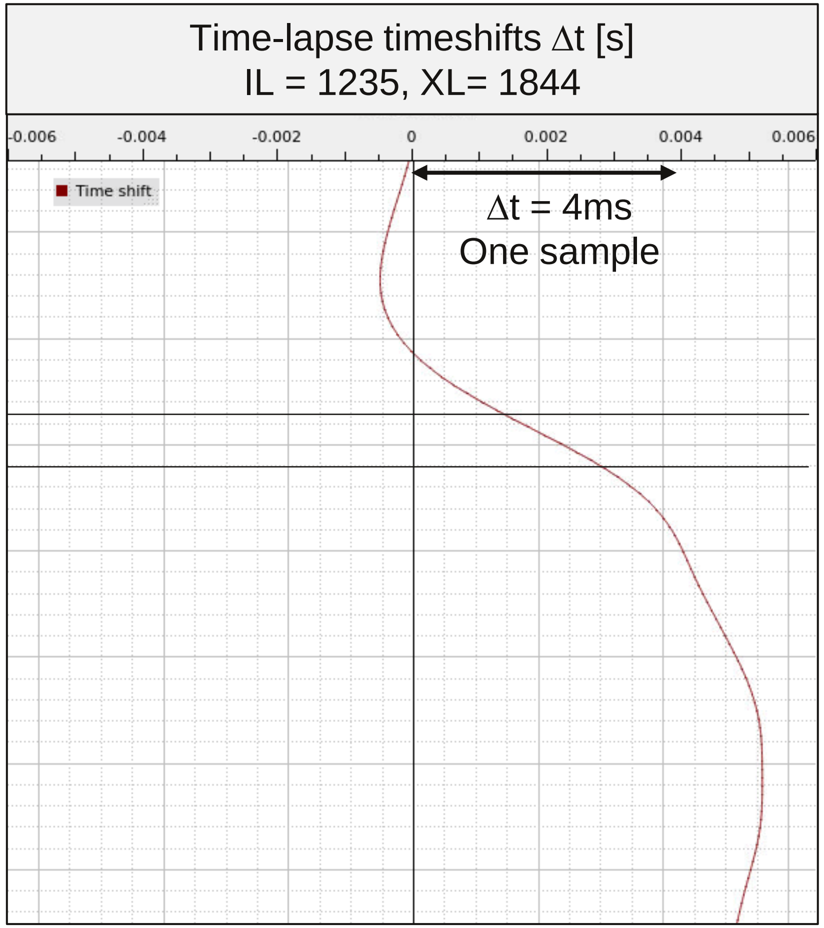
Timeshifts and timestrains for 4D interpretation



Sample-by-sample estimation of timeshifts between base- and monitor surveys



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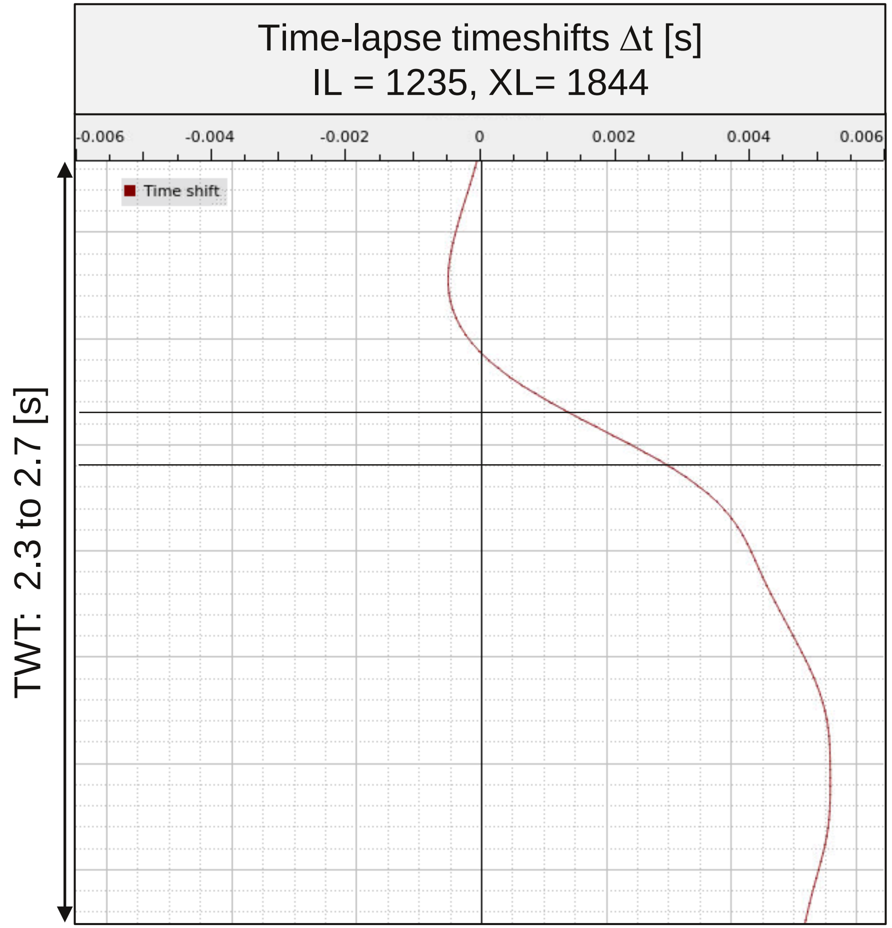
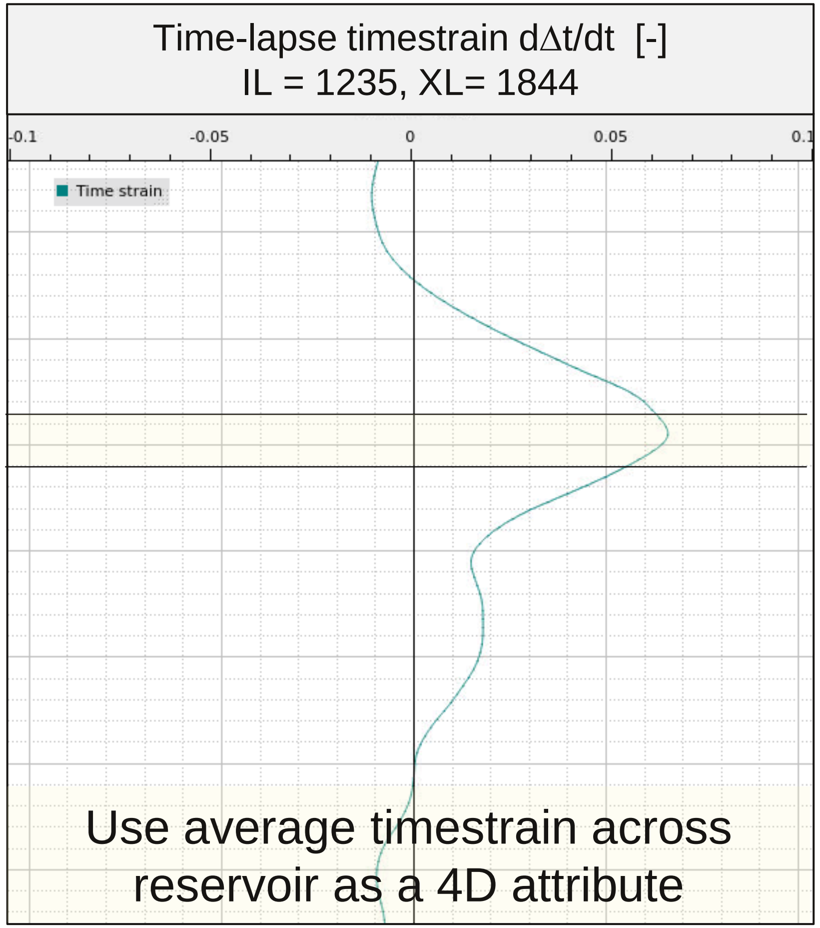
Timeshifts and timestrains for 4D interpretation



dΔt/dt

Computing time-strains from timeshifts by a vertical derivative



Use average timestrain across reservoir as a 4D attribute

Vertical derivative is calculated using a 5-point operator (Savitzky-Golay), with (1/12, -8/12, 0, 8/12, -1/12)/SampleInterval

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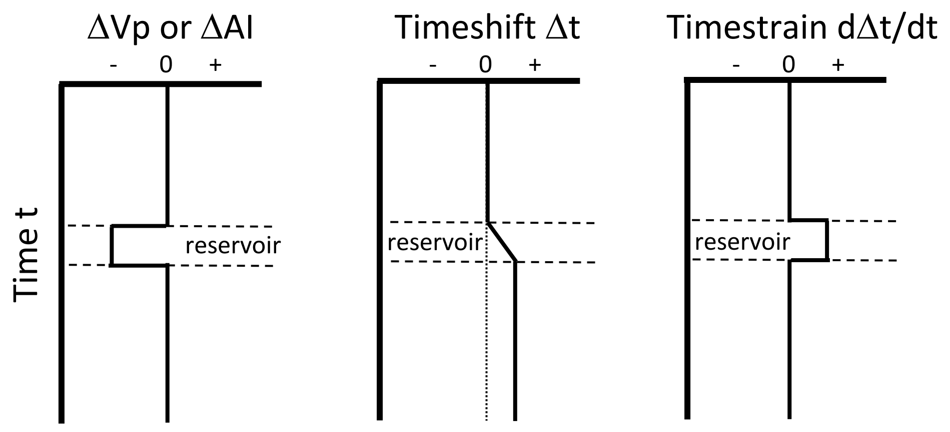
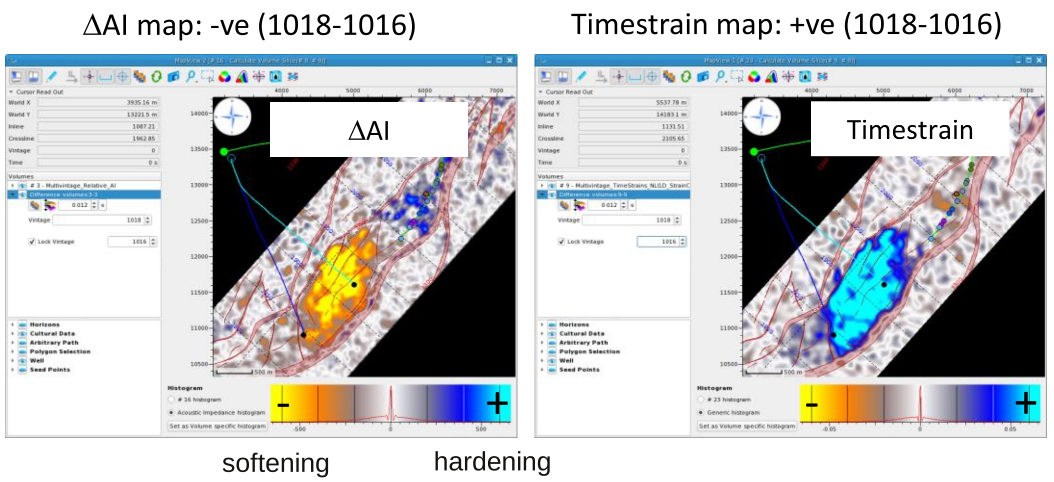
Timeshifts and timestrains for 4D interpretation

Conceptual model for causes of production induced time-lapse timeshifts



Reservoir: Pressure increase, or gas out-of-solution → velocity decrease

Application to field data



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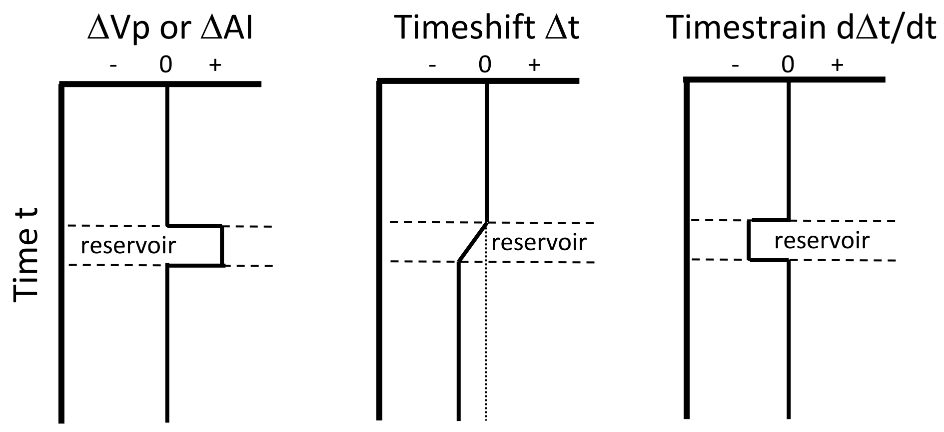
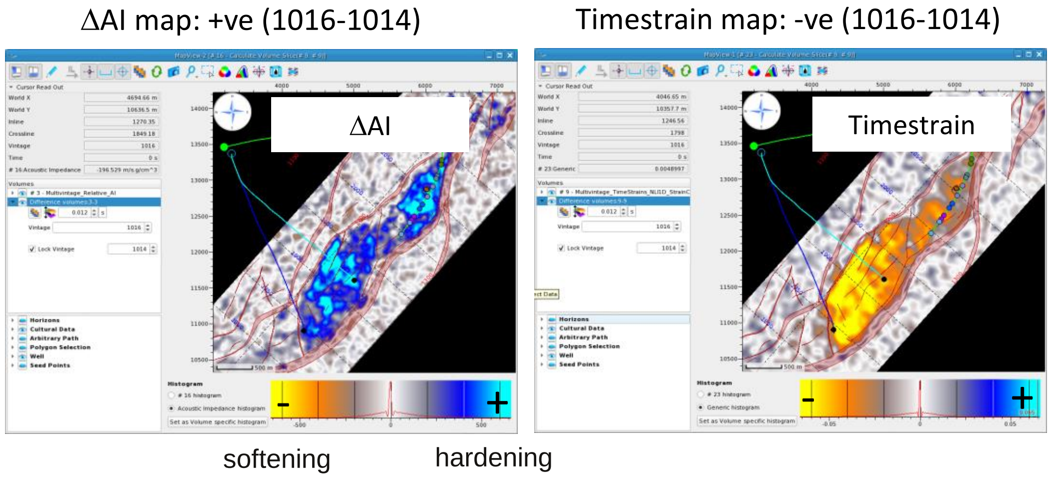
Timeshifts and timestrains for 4D interpretation

Conceptual model for causes of production induced time-lapse timeshifts



Reservoir: Pressure drop, or water-replacing-oil → velocity increase

Application to field data



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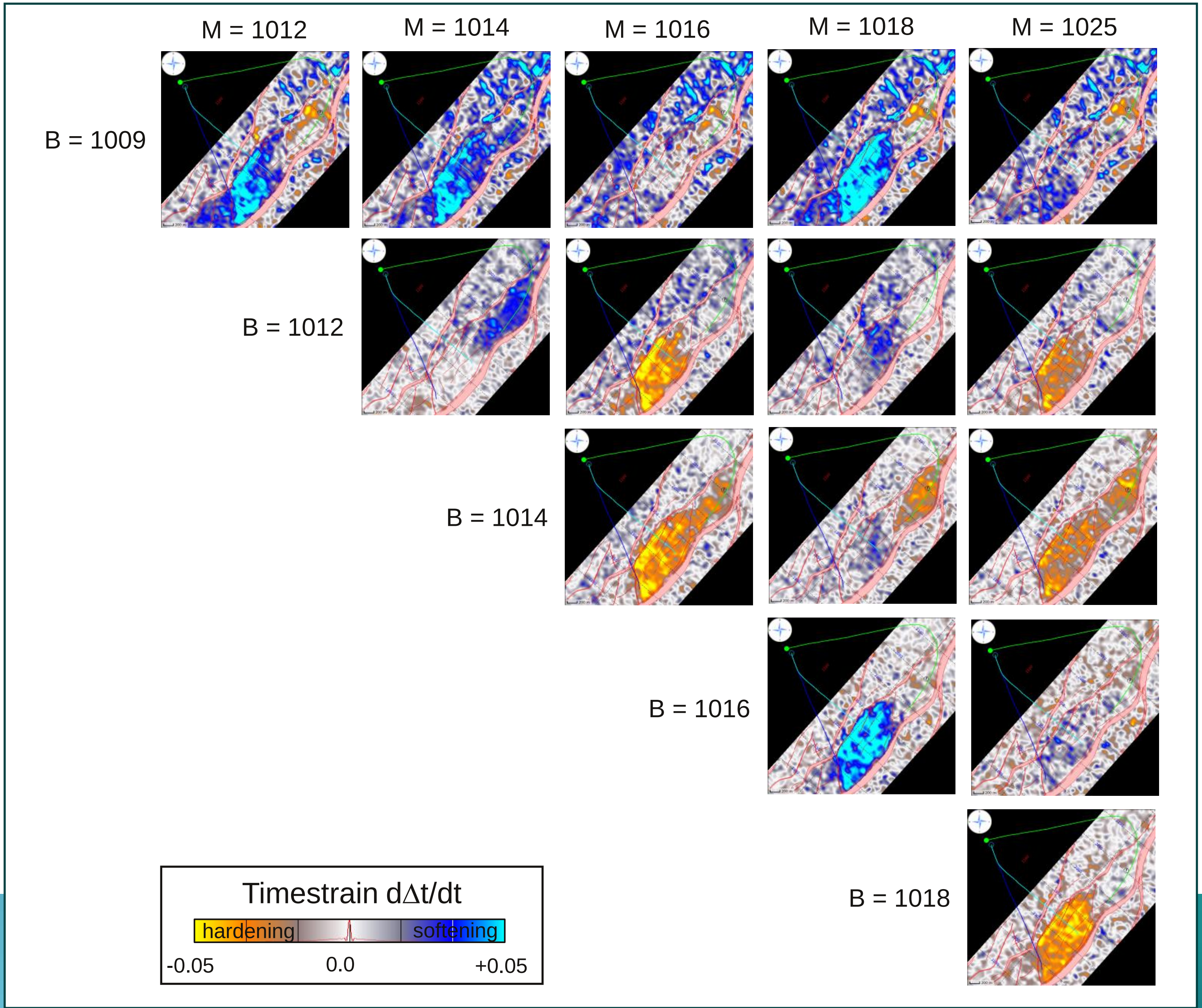
Timeshifts and timestrains for 4D interpretation



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Background

Timeshifts and timestrains for 4D interpretation

Production timeline