

THAILAND SPWLA

AUTOMATING DEPTH SHIFTING

OVERVIEW

- How is wireline data recorded?
- What is depth shifting and why do we need to do it?
- Overview of approach to automate depth shifting
- Results and discussion

No answers yet! This is a work in progress...

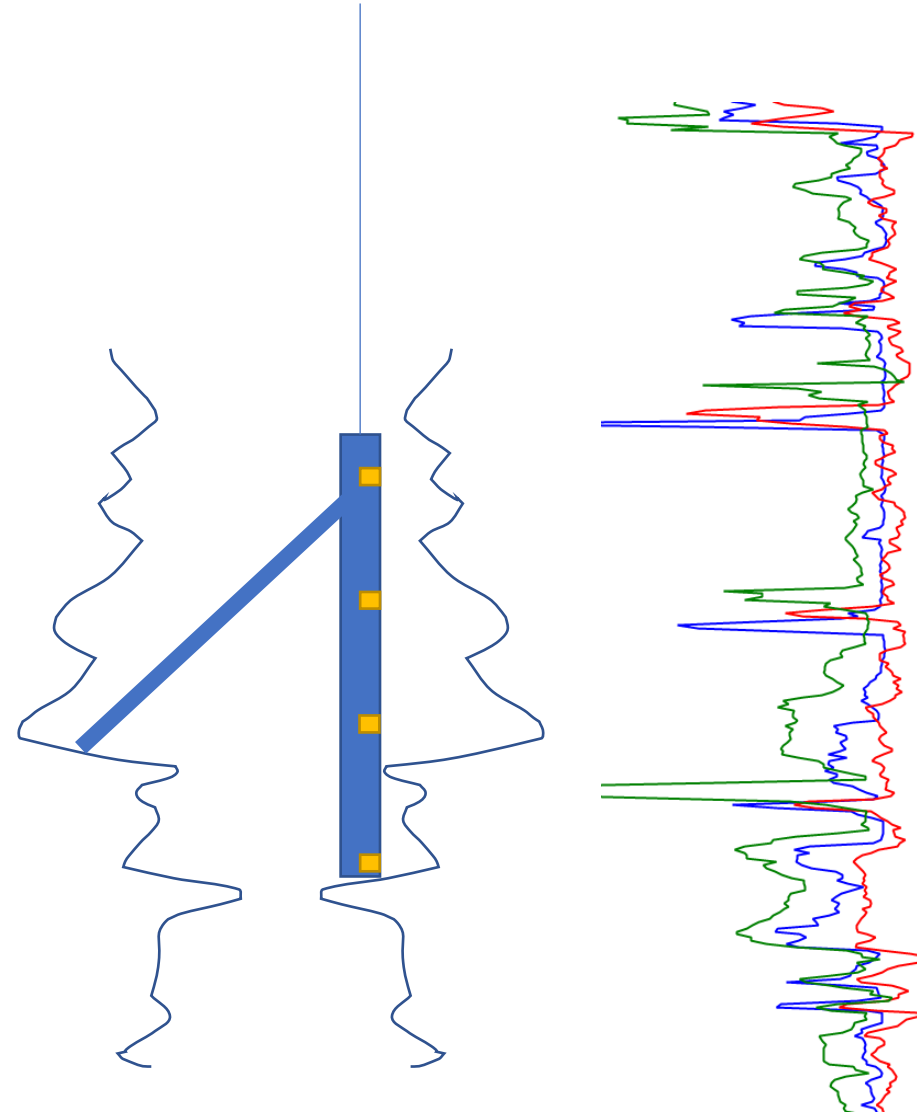


MAKING LOGS ON DEPTH

- ◆ Non-wireline measurements can be off depth due to run-run correlation/tie-in, etc.
- ◆ Wireline measurements are more susceptible to mismatches in depth due to the way the data is recorded and the physical mechanism by which the tools are conveyed

HOW A WIRELINE LOG IS RECORDED

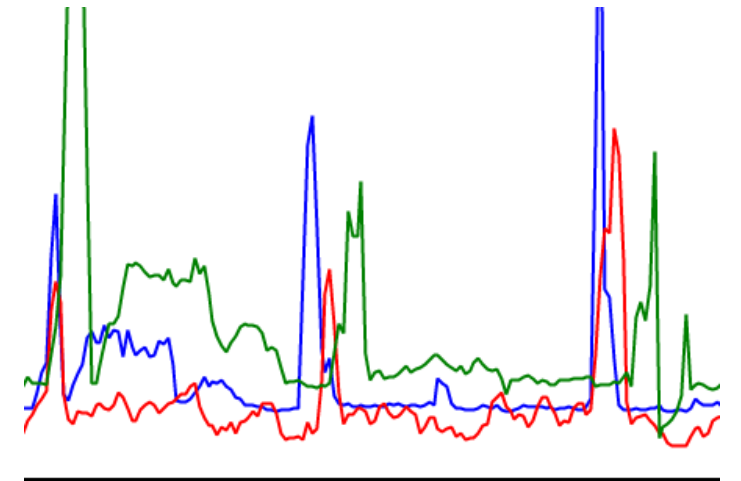
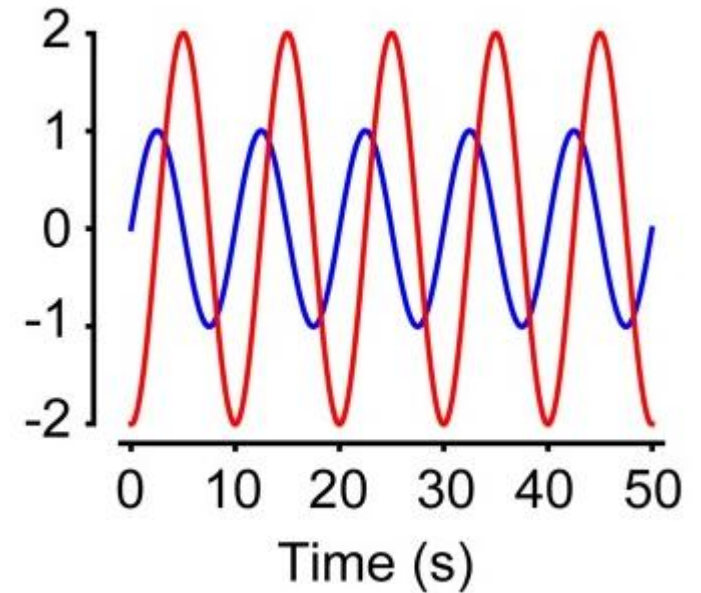
- Measurements are made in time and need to be converted to depth
- Continuously recording data from tools (at different sensor points) and using depth measurement device to place the data in depth
- Stick and pull, key-seating, yo-yoing, cable stretch, incorrect tool-diagrams in acquisition software, accelerometer corrections, log digitization, etc. can cause data to be off-depth from reference measurement



Tool strings can be hundreds of feet long

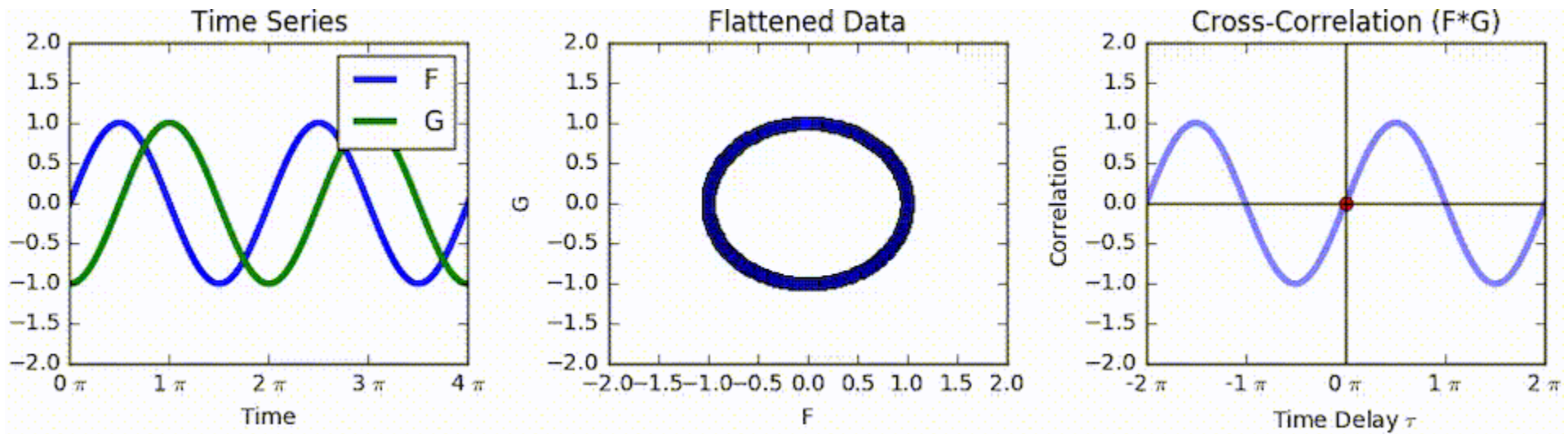
THE PROBLEM OF CORRELATION

- Time series analysis
- Cross correlation
- Easier for the geophysicists and electrical engineers*
- Each log measurement is not periodic and may scale differently in depth due to stretching and compression of the signal



SOLUTIONS

- For seismic traces and signals there are correlation algorithms that work well with semi-periodic data



- But what do we do for wireline logs?

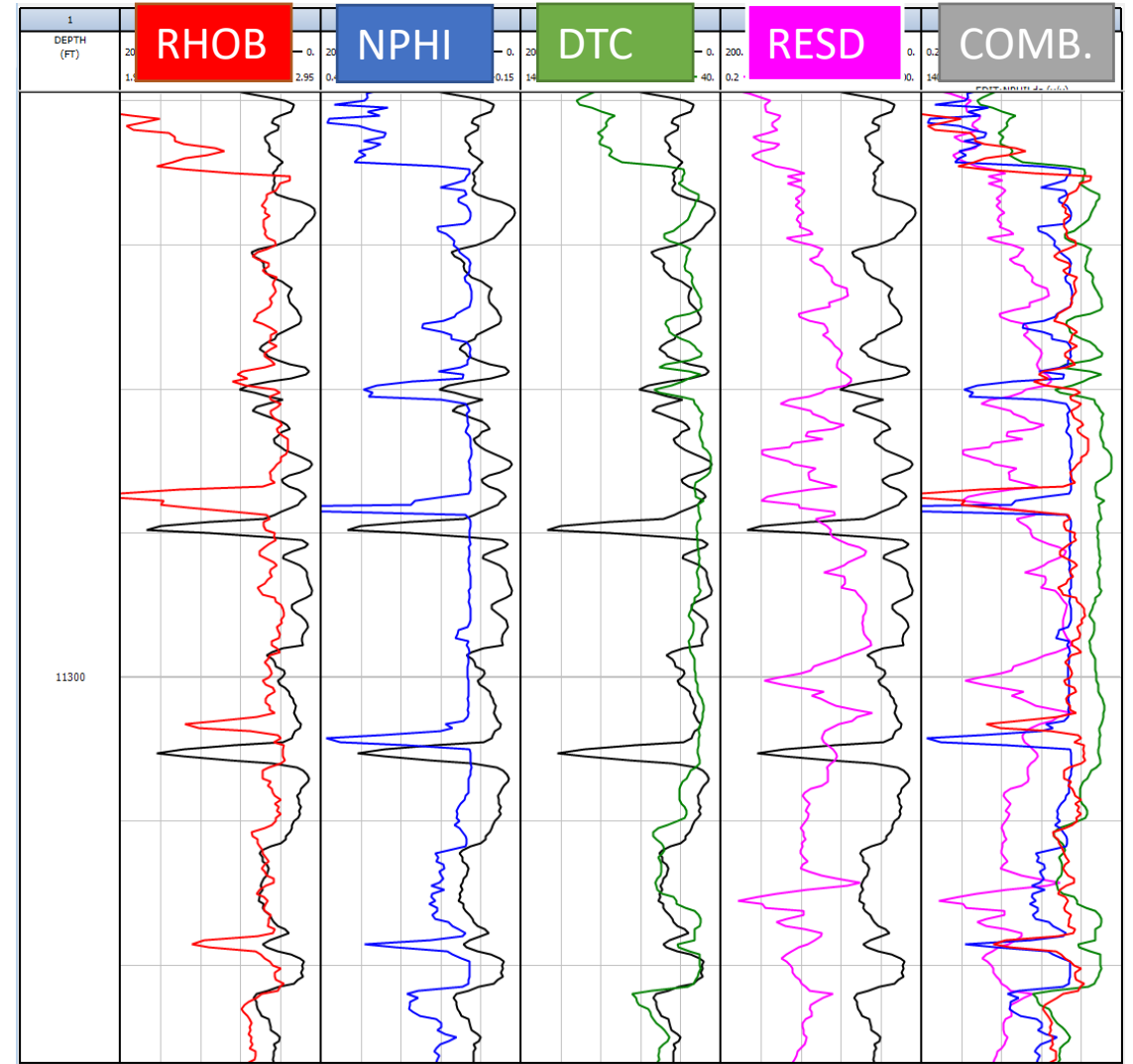
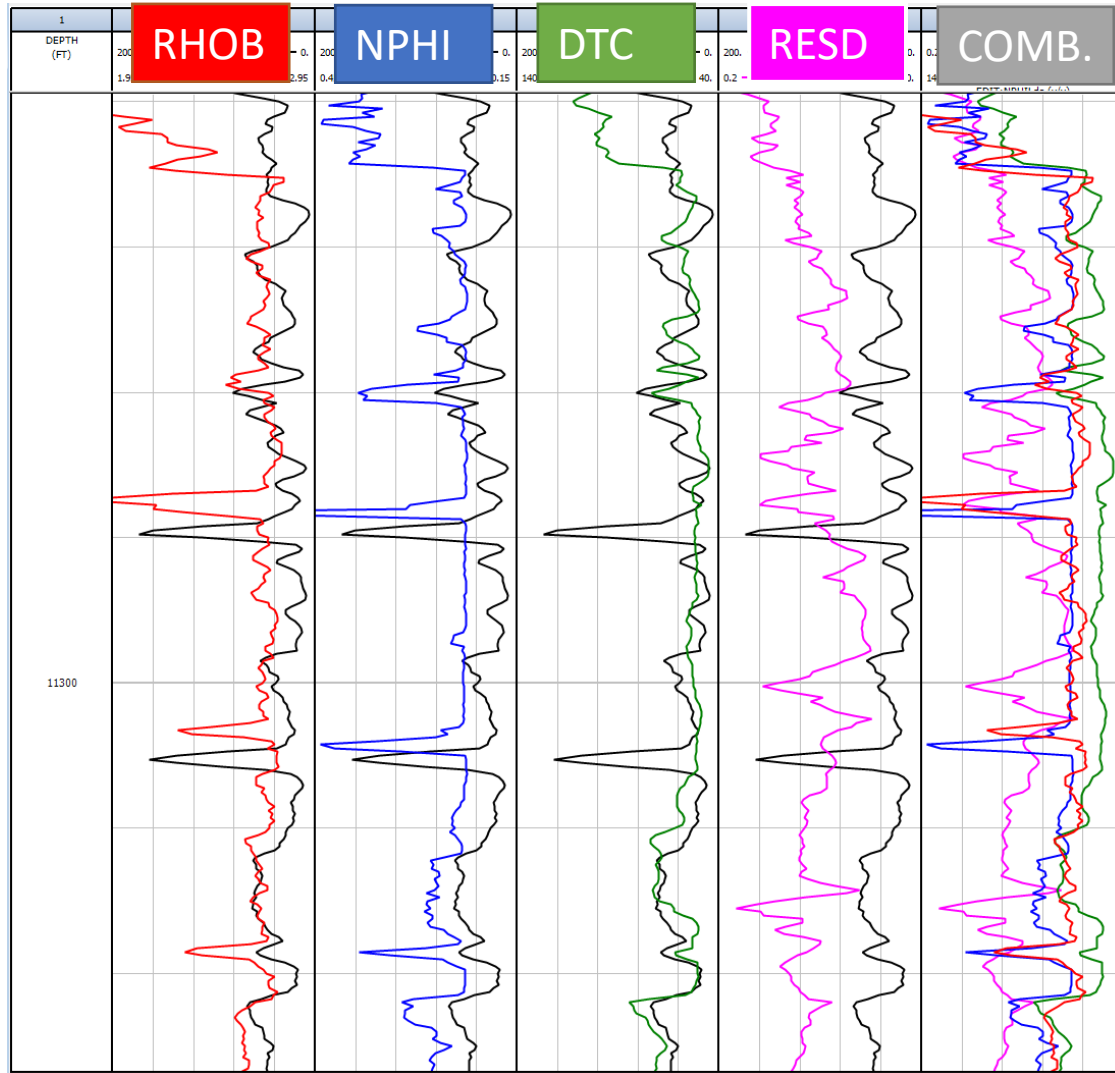
WHAT IS DEPTH SHIFTING?

- ◆ A single reference should exist for everything to tie back to—usually this is GR from the initial logging run
- ◆ All data need to be correlated or synchronized in depth with this reference curve, they may have positive or negative correlations to it (or both)
- ◆ There is bulk shifting of separate runs to tie in, but even within individual logging runs, depth shifts need to be performed on each tool measurement
- ◆ Sometimes there are markers or areas where things are correlated well to hang our hat on, in other areas things get artistic...

COLORS AND NOMENCLATURE

- 🔹 Gamma Ray : Black
- 🔹 Neutron Porosity: Blue
- 🔹 Bulk Density: Red
- 🔹 Deep Resistivity: Pink/Fuchsia
- 🔹 DTC Sonic: Green

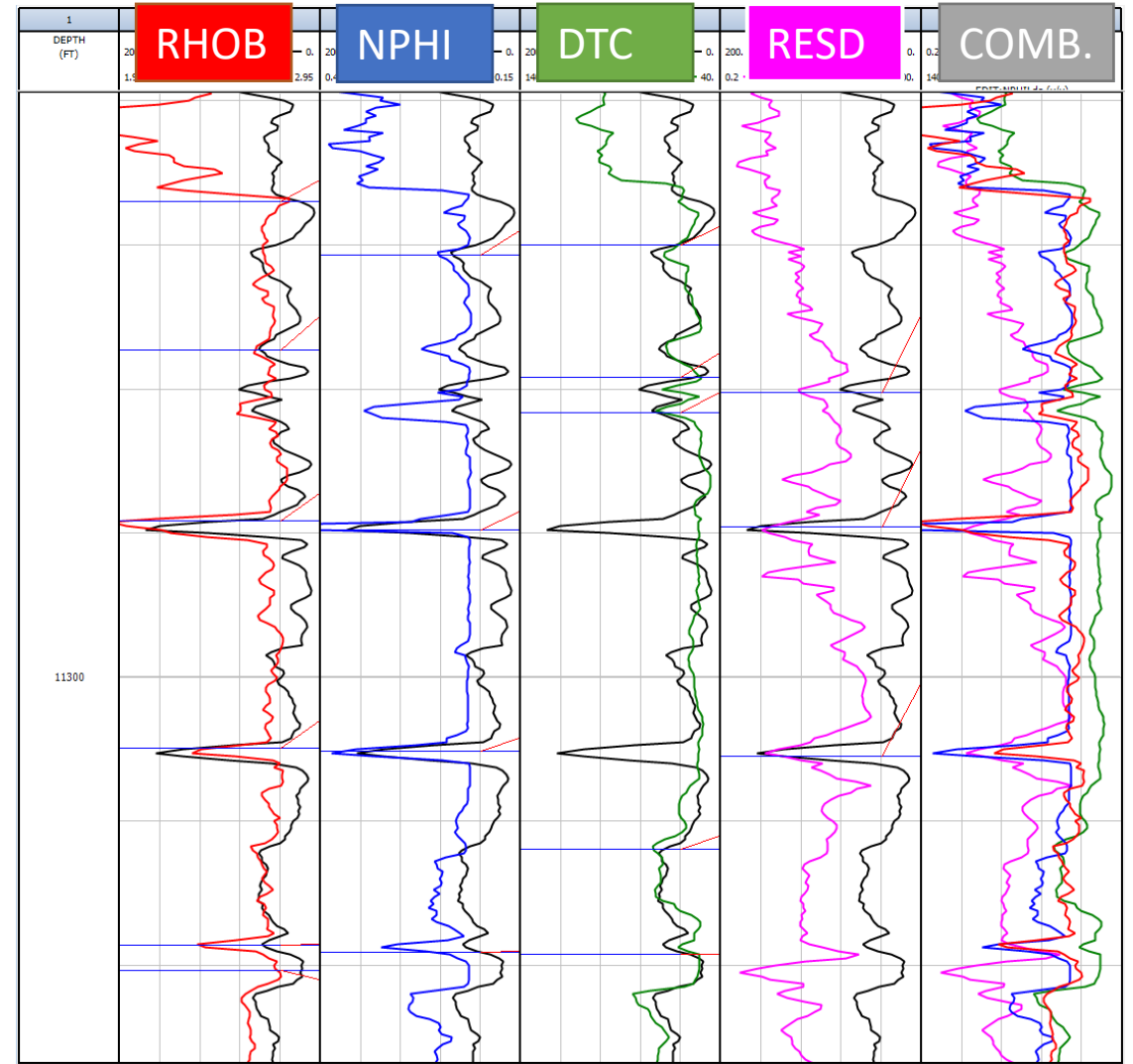
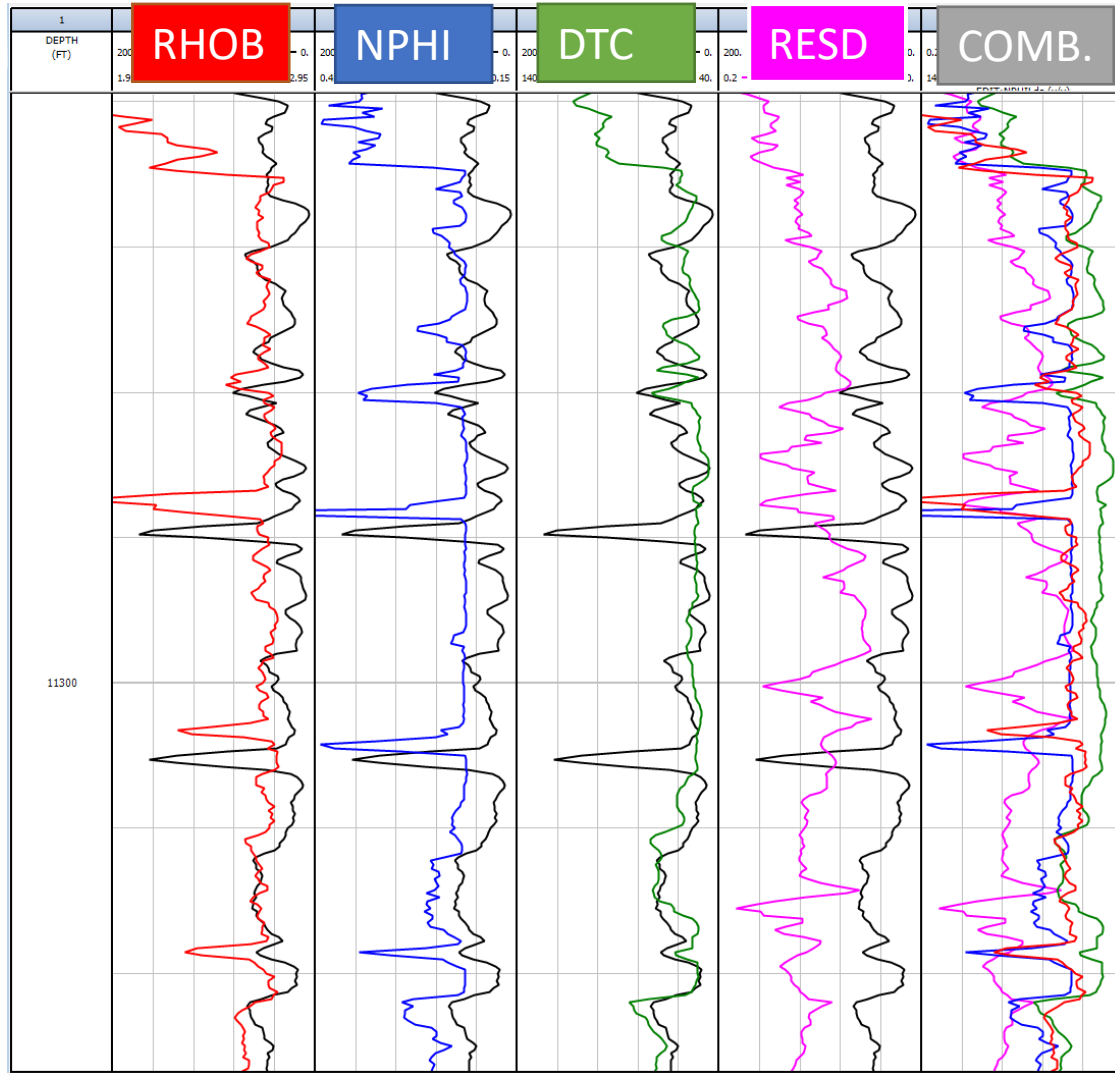
EXAMPLE OF DEPTH SHIFTING



Data from University Lands 7-16 #10



EXAMPLE OF DEPTH SHIFTING



Data from University Lands 7-16 #10



AUTOMATING THE PROCESS

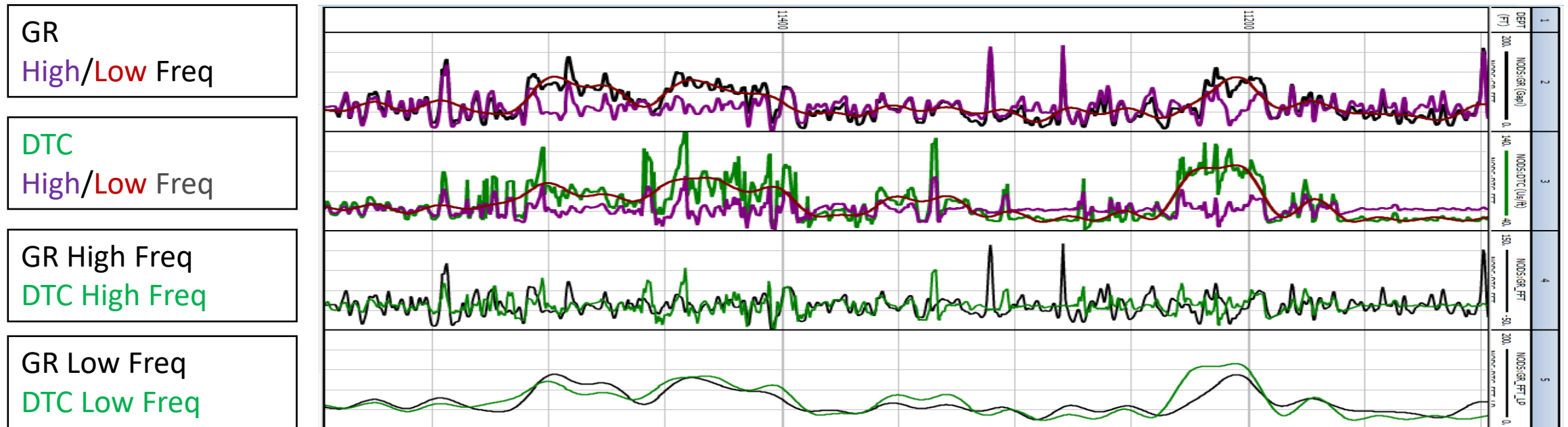
- ◆ Different ways to do this
 - ◆ Attempt to re-create the steps a human would take
 - ◆ Employ alternative techniques leveraging mathematics and algorithms
 - ◆ Let the computer run wild with a bunch of parameters and methods to determine what works best

BULK SHIFTING

- In the event of a gross offset, we need a good starting point where cross-correlation can help
- Bulk shift the data to the reference curve and get it sort of on depth
- We *may* run filters on the data prior to shifting

FILTERING

- High or low frequency filtering to improve VRES match and overall trend (remove noise) using FFT
- Low frequency component match vs. high frequency

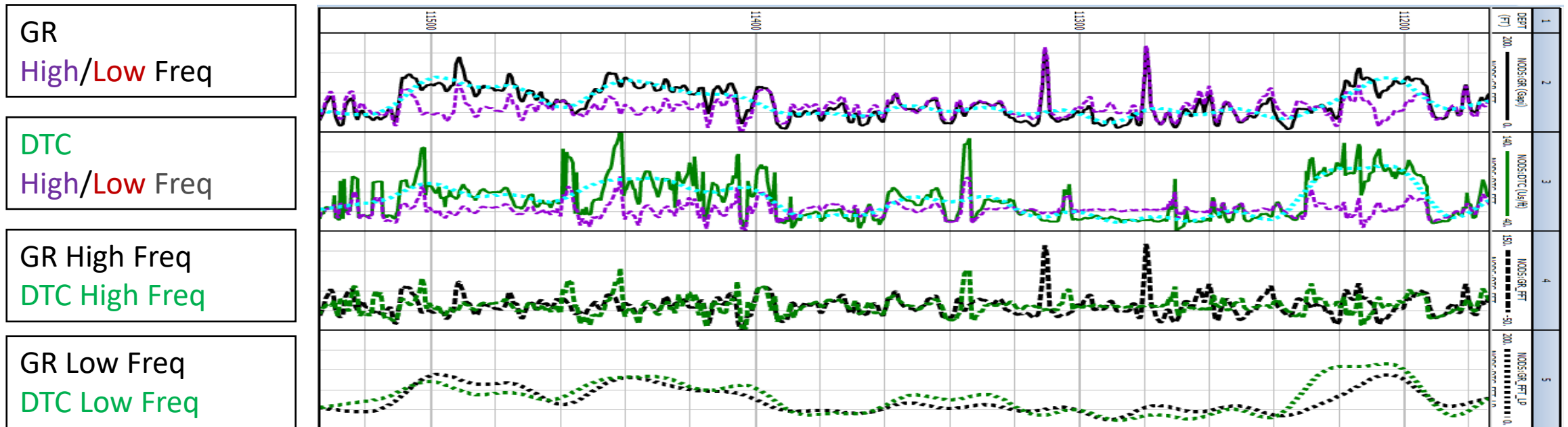


Apologies to the color blind



FILTERING

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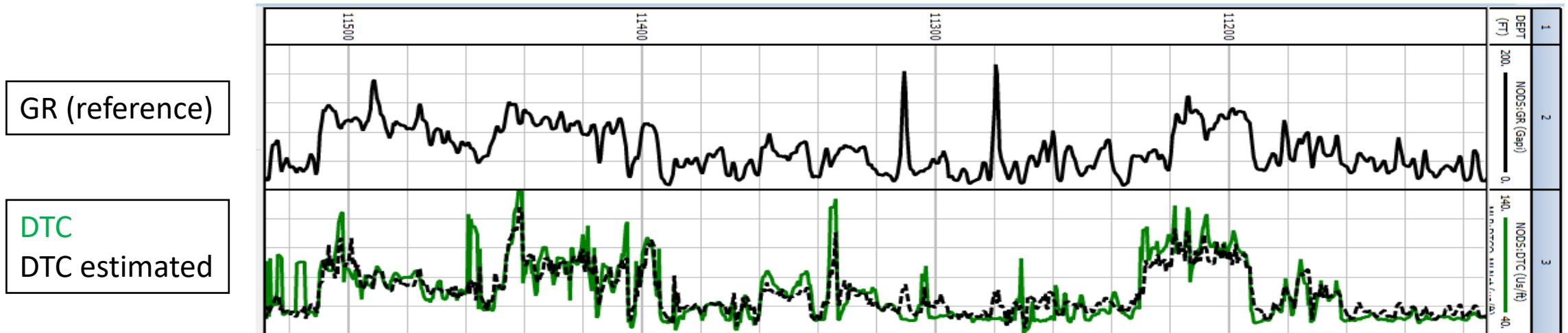


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ESTIMATED CURVES

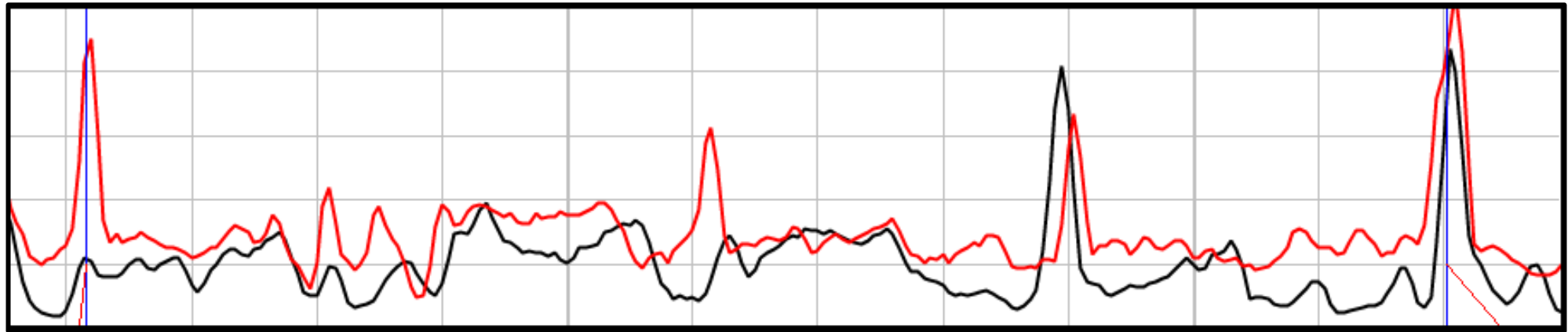
- Using curves that are on depth to estimate curve that's off depth, results will depend on how bad the curves are off depth



Example shown only using GR/RES and Fast Tree Regression to predict DTC

ANCHOR POINTS

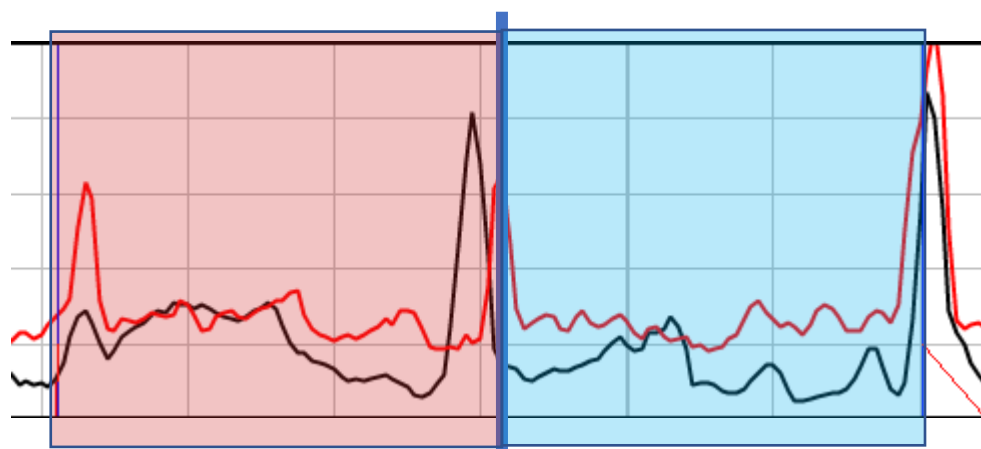
- ◆ Find *anchor points* where there is a high correlation between the curves, or by using windows, or statistics (outliers)
- ◆ At least 2 points are necessary to fix the data in place, so that stretching/compressing is possible



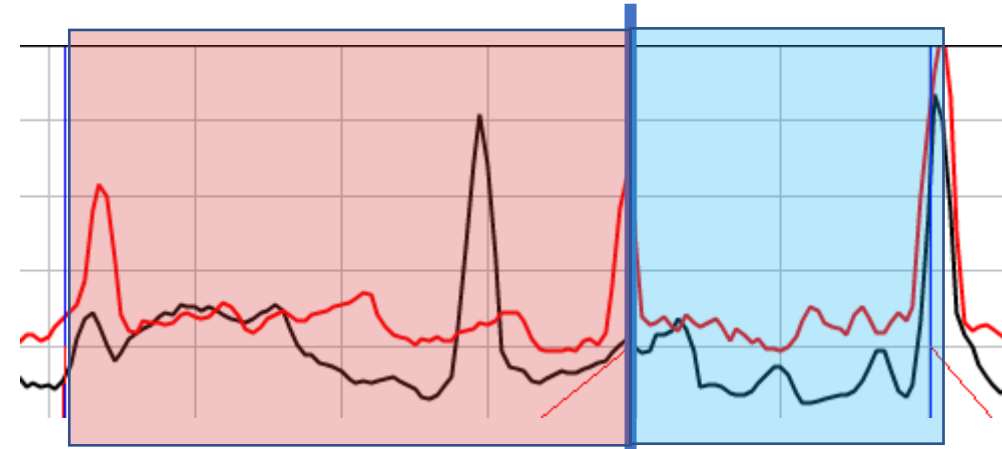
Start with two anchor points to fix the data in place
(find these by looking for areas of high correlation, or
they might be just the ends of the array)

WHAT DO YOU MEAN STRETCH/COMPRESS?

- Take the two end points and select every point in-between as a *middle* point, then stretch the left and compress the right segment and vice versa, limiting max stretch/compression
- Use interpolation algorithms to modify the data
- Select the best run based on user criteria (max shift, polarity, etc.)
- Keep track of the direction



Index in middle position

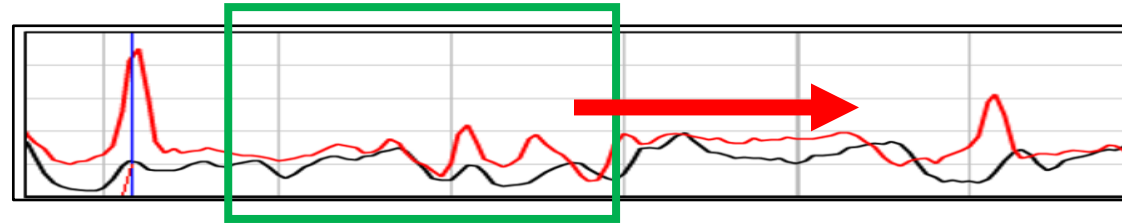


Index shifted right

HOW TO DEPTH SHIFT DOWN A WELL

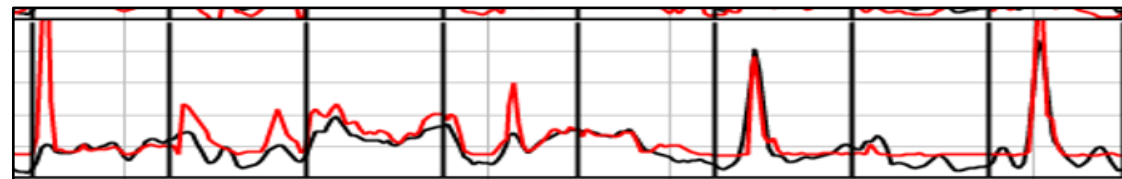
- One possible way of handling this is to use a window to seek correlations and start at the top of the well (left side) and work to the bottom (right side) anchoring where shifts occur

Moving w/window



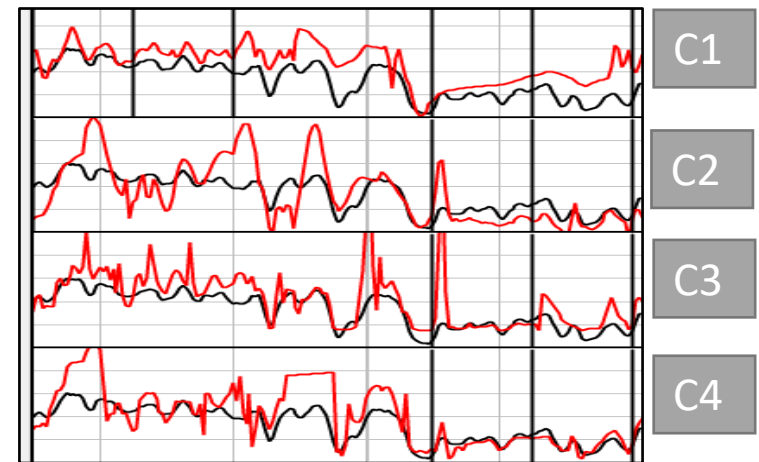
- Another way is to fix anchor points down the well using R2 or windows and manipulate the data between each set of anchors
- This does present a challenge if the anchor lands in the wrong spot, which happens alot*

Fixed anchors (high R2 or fixed window size)



DIRECTION

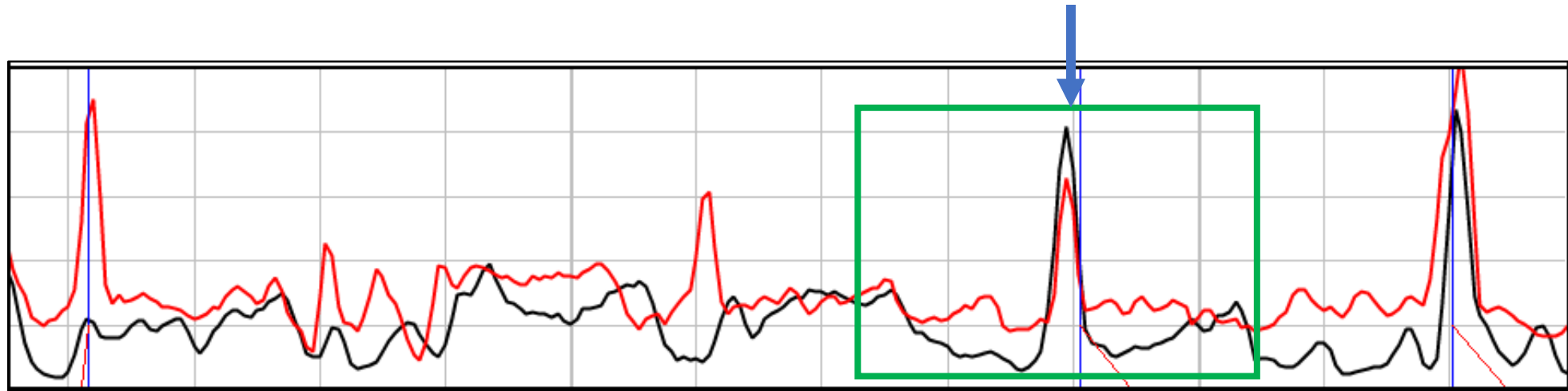
- It should *generally* be the case that whatever direction some of the most significantly correlated curves (i.e., NPHI, DTC) move in, the others should follow suit
- Bookkeeping task: keep track of the direction of shifts in best correlating curve pairs and allow the option to force other curves to adhere to it
- Conflict resolution
- Subdivision of windows



Different sized windows

WINDOWS VS. ANCHORS

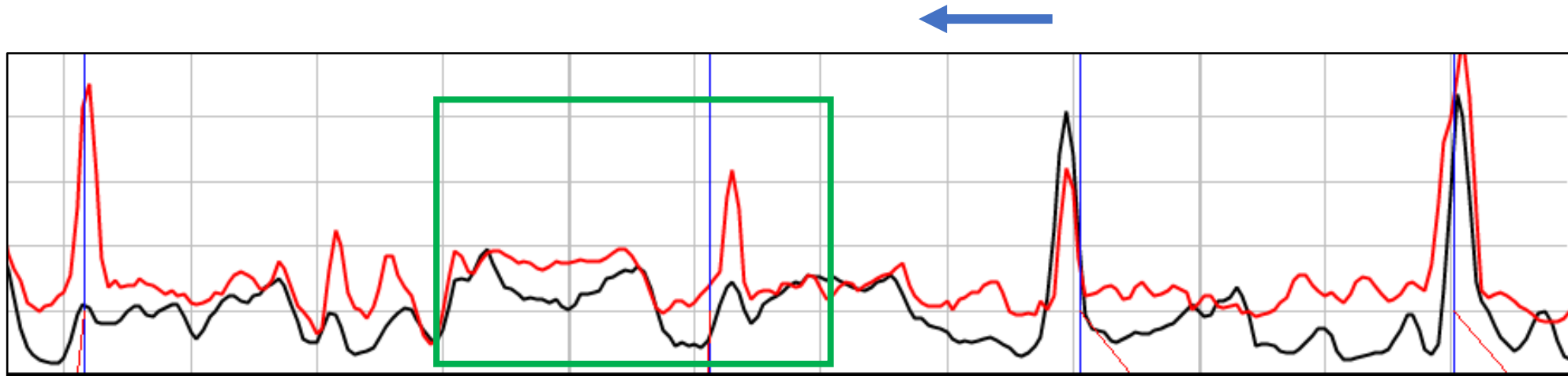
Make a window around the data and compress/stretch
The data inside the window until a maximum correlation
Is achieved



Start with two anchor points to fix the data in place
(find these by looking for areas of high correlation, or
they might be just the ends of the array)

WINDOWS VS. ANCHORS

Fix the data that's been shifted
Move the window to a new spot and repeat the process



Start with two anchor points to fix the data in place
(find these by looking for areas of high correlation, or
they might be just the ends of the array)

CONTROL PARAMETERS

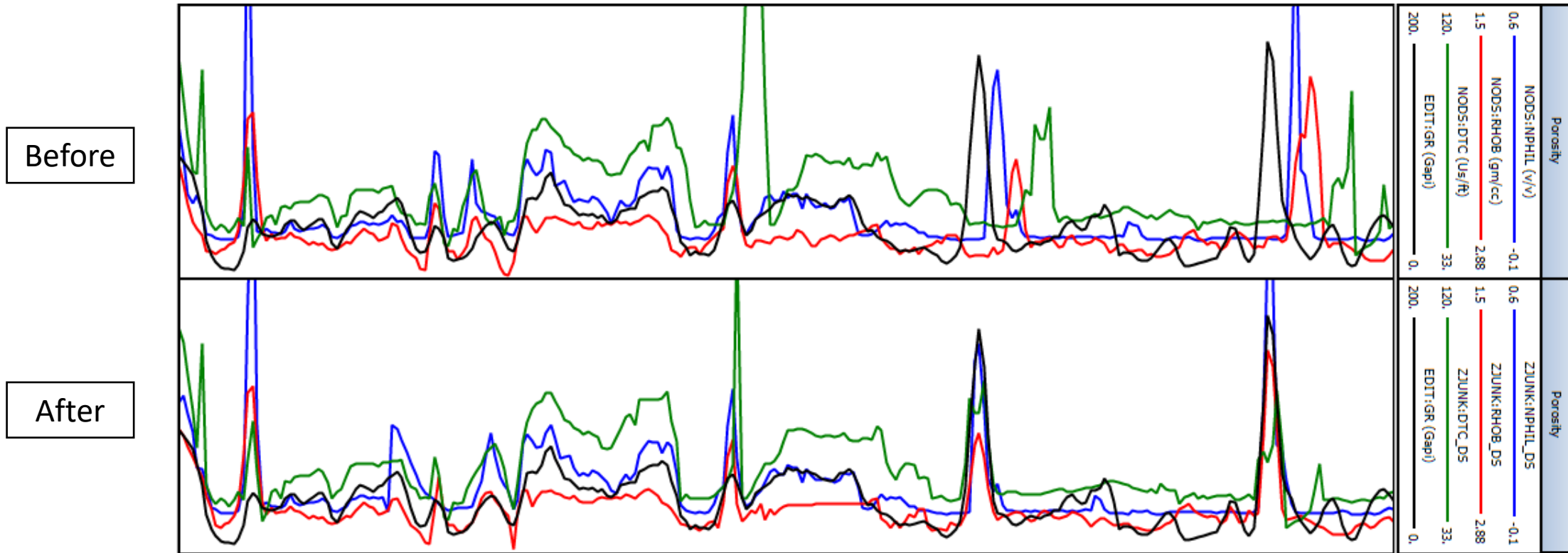
- ◆ Size of window
- ◆ Anchor points
- ◆ How much of a stretch shift is acceptable
- ◆ How much of a compression shift is acceptable
- ◆ R2 coefficient hurdle
- ◆ Polarity of correlation
- ◆ Number of shifts able to occur within a specified interval length
- ◆ Frequency filtering of data
- ◆ Multiple correlation sensitivity runs
- ◆ Curve prediction

There are many possibilities here...



EXAMPLE (SINGLE SHIFTS TO REFERENCE)

- Not perfect, but not bad



SHIFTS WITH ANCHOR POINTS



Fixed window / R2 anchors



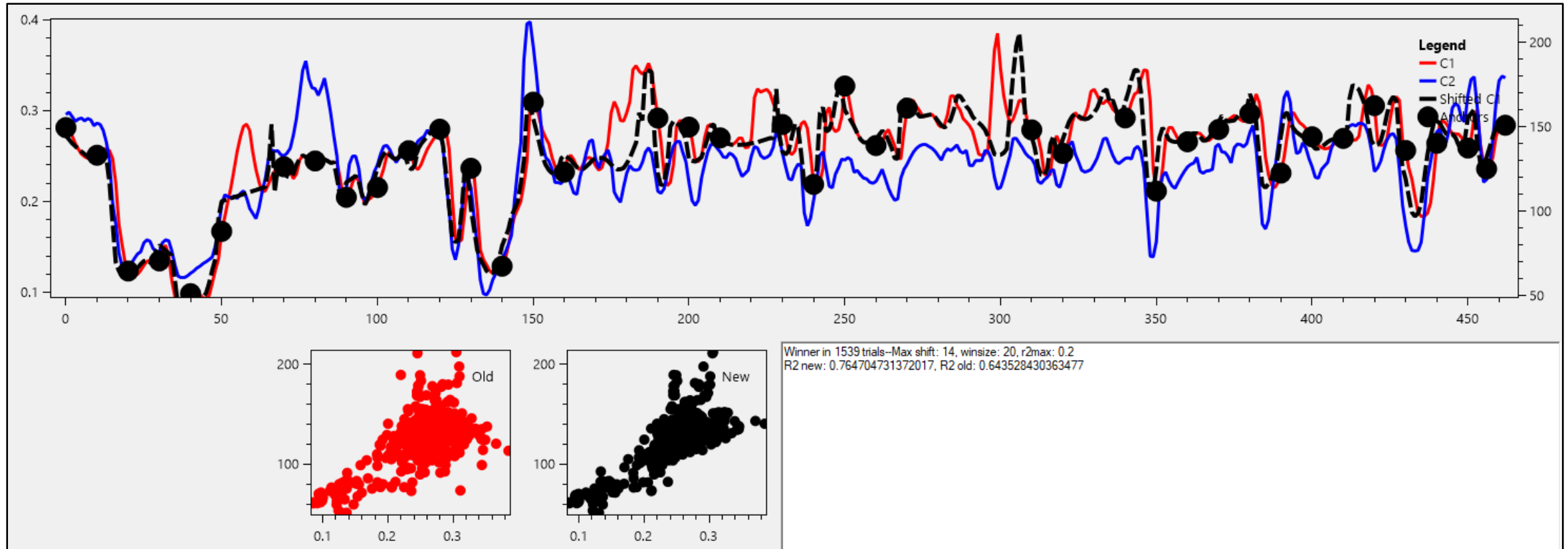
SHIFTS USING RUNNING WINDOW / ANCHORS



CAN WE DO BETTER?

- Leverage the computer to do the heavy lifting... sensitivity to control parameters
- Why only shift each curve to the reference curve? Why not shift the curves to each other as well?
- Can we setup some sort of logic to check everything for a best fit solution?

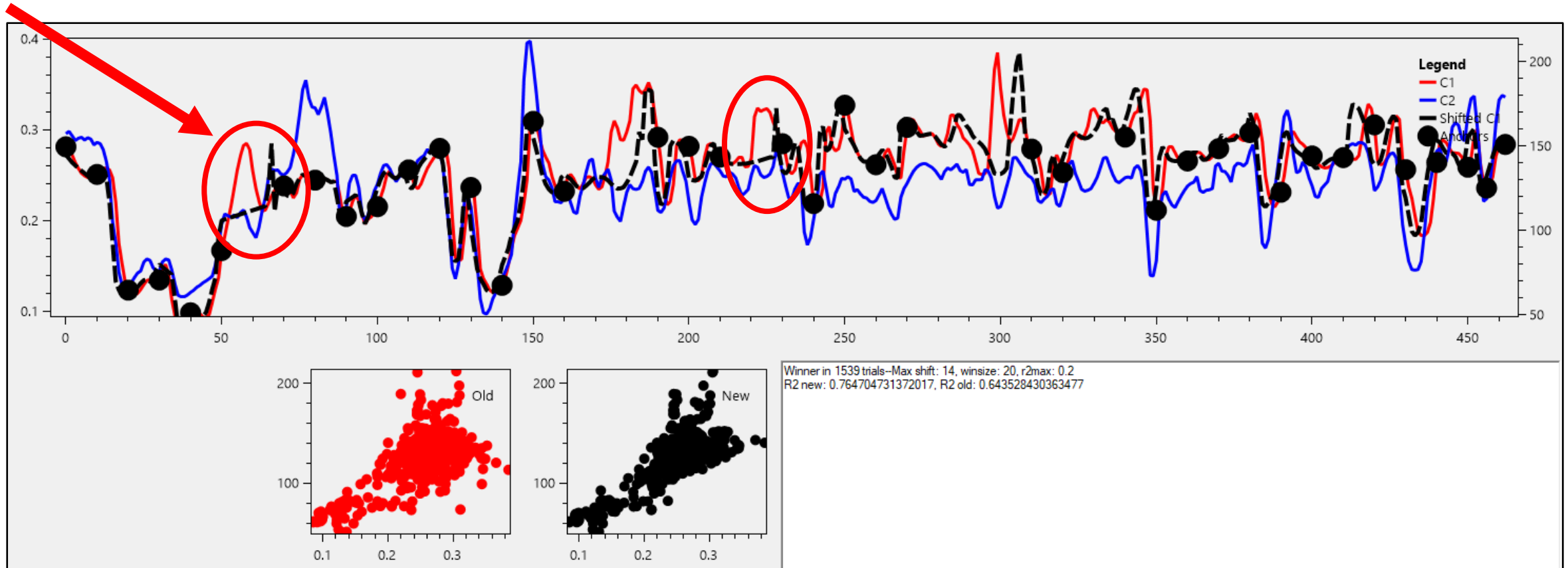
SENSITIVITY EXAMPLE



1539 trials run with different parameters to find best overall R2 fit



FAIL: DISTORTION OF DATA

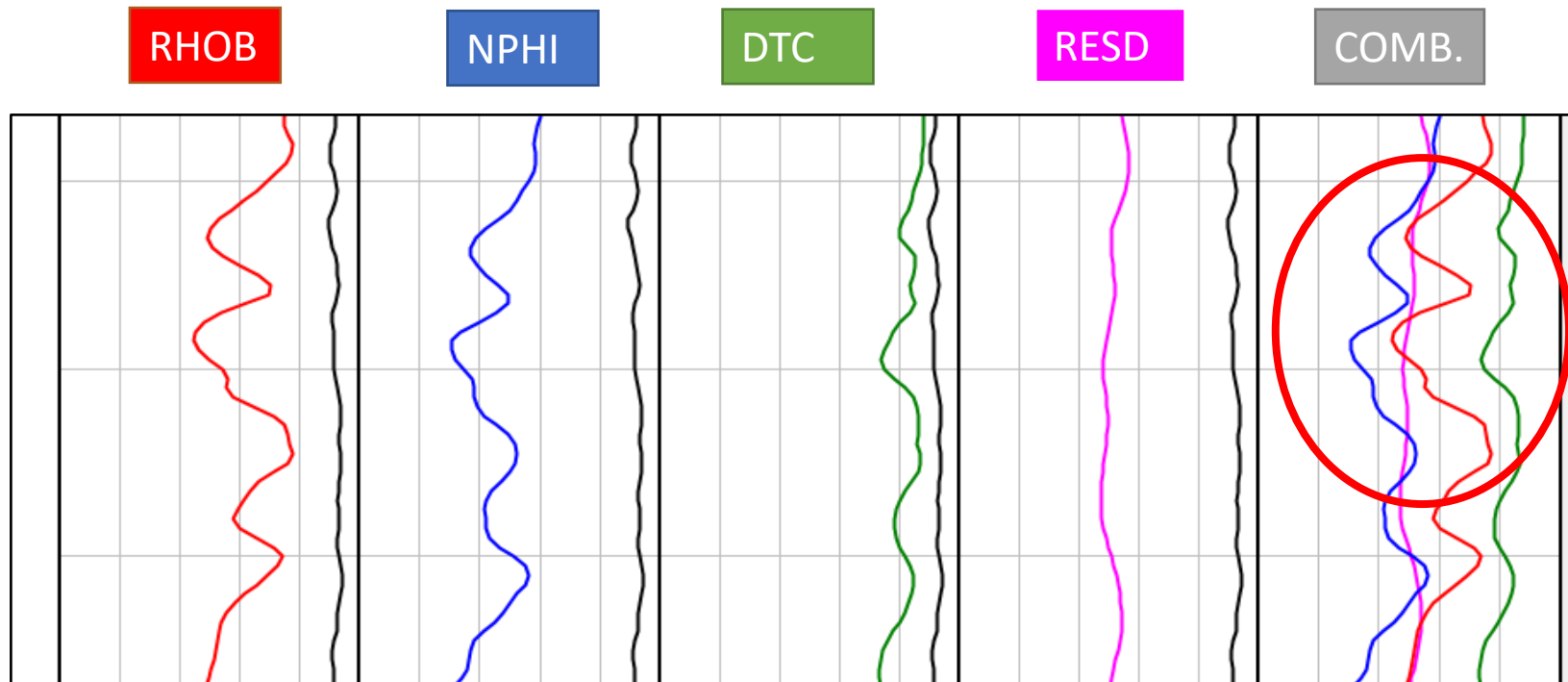


In this case, since we let the parameters *run wild*, over compression occurred in two places that is not acceptable

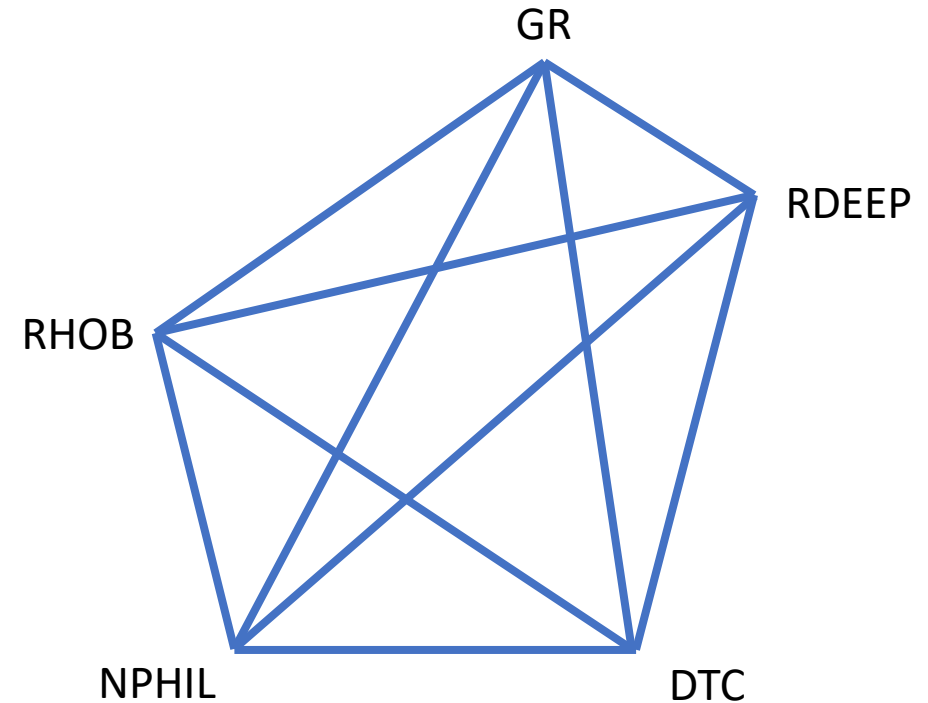
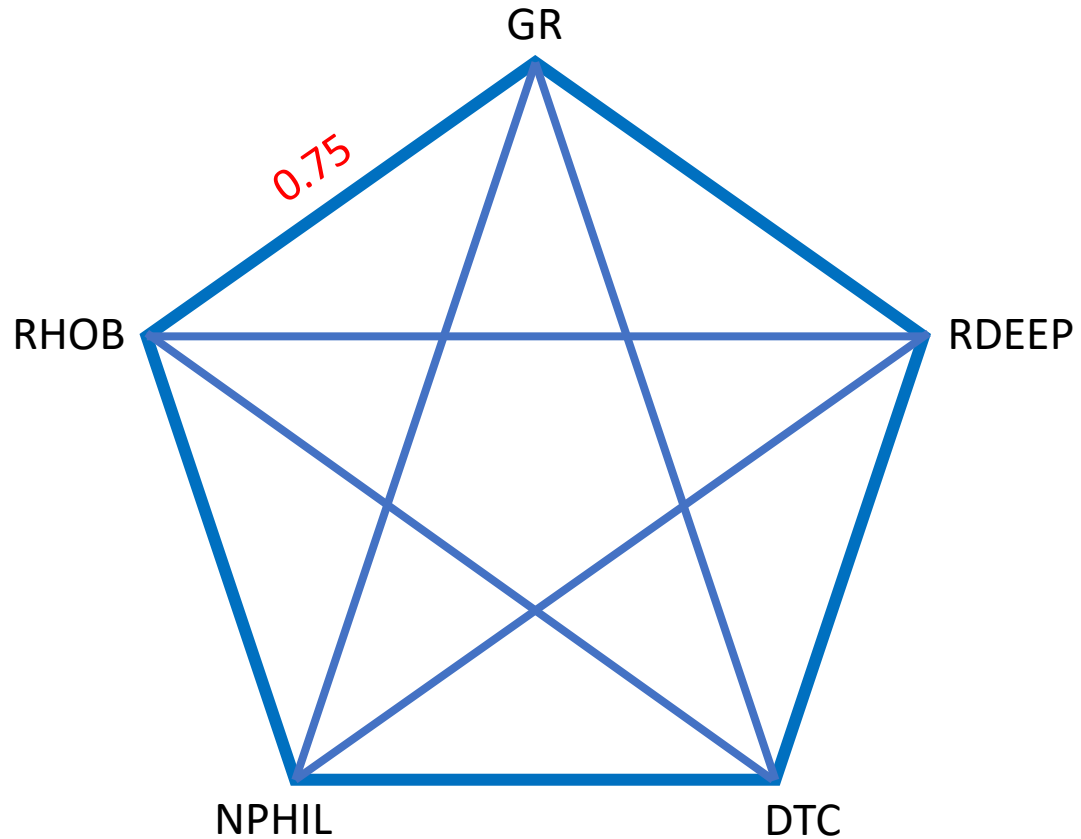
1539 trials run with different parameters to find best overall R2 fit

MULTIPLE DEPTH SHIFT PAIRS

- What about this issue?



MULTIPLE DEPTH SHIFT PAIRS



Let the computer run a bunch of scenarios (Monte Carlo) and find the best fit
Each curve should have a maximum correlation to reference, but also to each other

Geometry not correct representation



METHODOLOGIES

- ◆ A lot of bookkeeping... need to shift a lot of times and keep track of results, directions, parameters, etc. *Computers are good at this.*
- ◆ Use combinatorics to find curve-pair combinations (nCk)
- ◆ Or sequentially shift curve-curve then to reference utilizing highest correlating curve to reference last, shifting everything along the way
- ◆ Best answer wins, but QC required by user, not fully automated!
- ◆ *There are many cases where even a human cannot figure out how to depth shift curves, so how is a computer going to do it?*

EXAMPLE

C1	C2	R2
DTC	GR	0.68539
NPHIL	GR	0.728916
RHOB	GR	-0.59871
RDEEP	GR	-0.31761
DTC	NPHIL	0.824265
DTC	GR	0.714054
DTC	RHOB	-0.81527
DTC	RHOB	-0.80618
DTC	GR	0.703484
DTC	NPHIL	0.833554
NPHIL	RHOB	-0.8088
NPHIL	GR	0.486156

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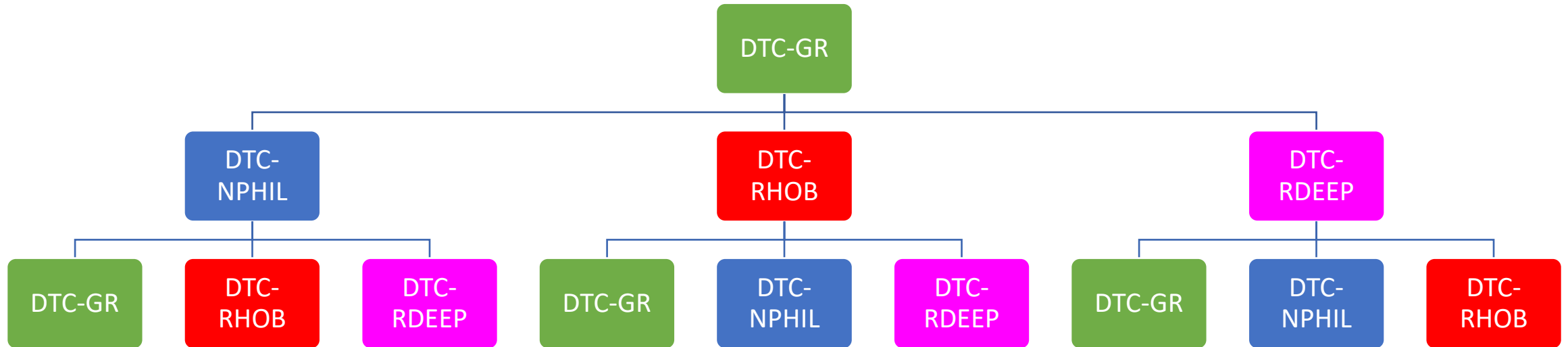
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CURVE PAIR INTERDEPENDENCIES



This is just one of many trees



SEQUENTIAL APPROACH (EXAMPLE)

- ◆ Shift RHOB to RDEEP (i.e., worst correlation)
- ◆ Shift RHOB/RDEEP to DTC, whichever is best, and apply the depth shift to the other curve
- ◆ Shift DTC/RHOB/RDEEP to NPHIL, whichever is best, and apply the depth shifts to the other curves
- ◆ Shift NPHIL to GR (i.e, best correlation) and apply shifts to all other curves

Other possibilities exist, but the approach is finite and sequential based on some curves having better correlations to the reference



AUTOMATING DEPTH SHIFTING REVIEW

- ◆ Lots of knobs and dials here – still very much a work in progress—*this needs to be put into practice and the data will tell us what to use*
- ◆ Some general steps
 - ◆ Frequency filter data to VRES match and get rid of noise
 - ◆ Use cross correlation to get things close in the event of gross offset
 - ◆ Stretch/compress curves and record direction and magnitude of shift, controlling over stretching and compressing using different types of windows
 - ◆ Depth shift other curves and curve-pairs to each other using various computed combinations evaluating results as group
 - ◆ QC/modify end results as necessary by hand with flags showing highest/lowest correlating windows/curves

WHAT WILL IT LOOK LIKE?

- Many simulation experiments to be setup, run and recorded
- Results to verify which method works the best with the least amount of unwanted data manipulation
- End goal is to minimize the number of clicks required to save interpreter wrists

CURRENT PROGRESS

- Software has been written, most contingencies programmed up, need to setup experimental engine to produce all relevant possible configurations and determine what works
- Run times are surprisingly fast considering array copy operation cost, using 12th generation i7 processor
- Once parameters and methodology has been determined by simulation and validated, put into practice on large data sets

QUESTIONS

- Thank you for your attention