3D Seismic Attributes to Define Structure and Stratigraphy – A Hands-On Short Course
Part 4: Data conditioning

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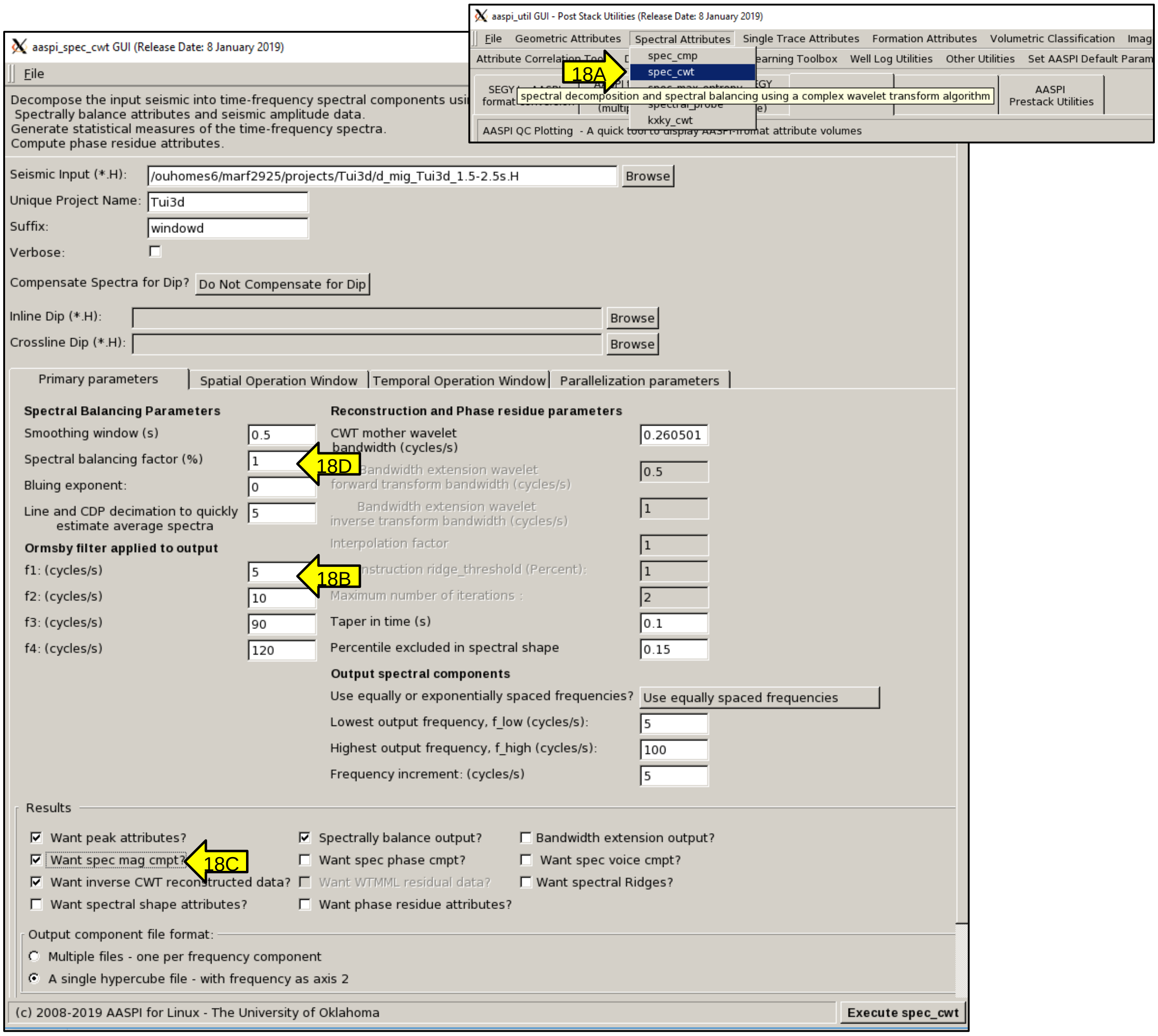
Introduction

Spectral balancing using the continuous wavelet transform program spec_cwt or spec_cmp

The AASPI has three spectral decomposition algorithms – continuous wavelet transforms (**spec_cwt**), which runs the fastest, complex matching pursuit (spec_cmp), which runs slowest but has higher temporal and spectral resolution, and constrained least-squares spectral analysis (spec_max_entropy), which also has very high temporal and spatial resolution. There is also a spectral cross-correlation algorithm (spectral_probe), which does not decompose a amplitude volume, but rather generates a suite of normalized crosscorrelation coefficients with a suite of sine and cosine 1-cycle wavelets. This algorithm (and spectral "voice" components as well) often highlights fault terminations better at one frequency than another.

To run **spec_cwt**, go to Volumetric Attributes → **spec_cwt** (18A) and invoke the following GUI

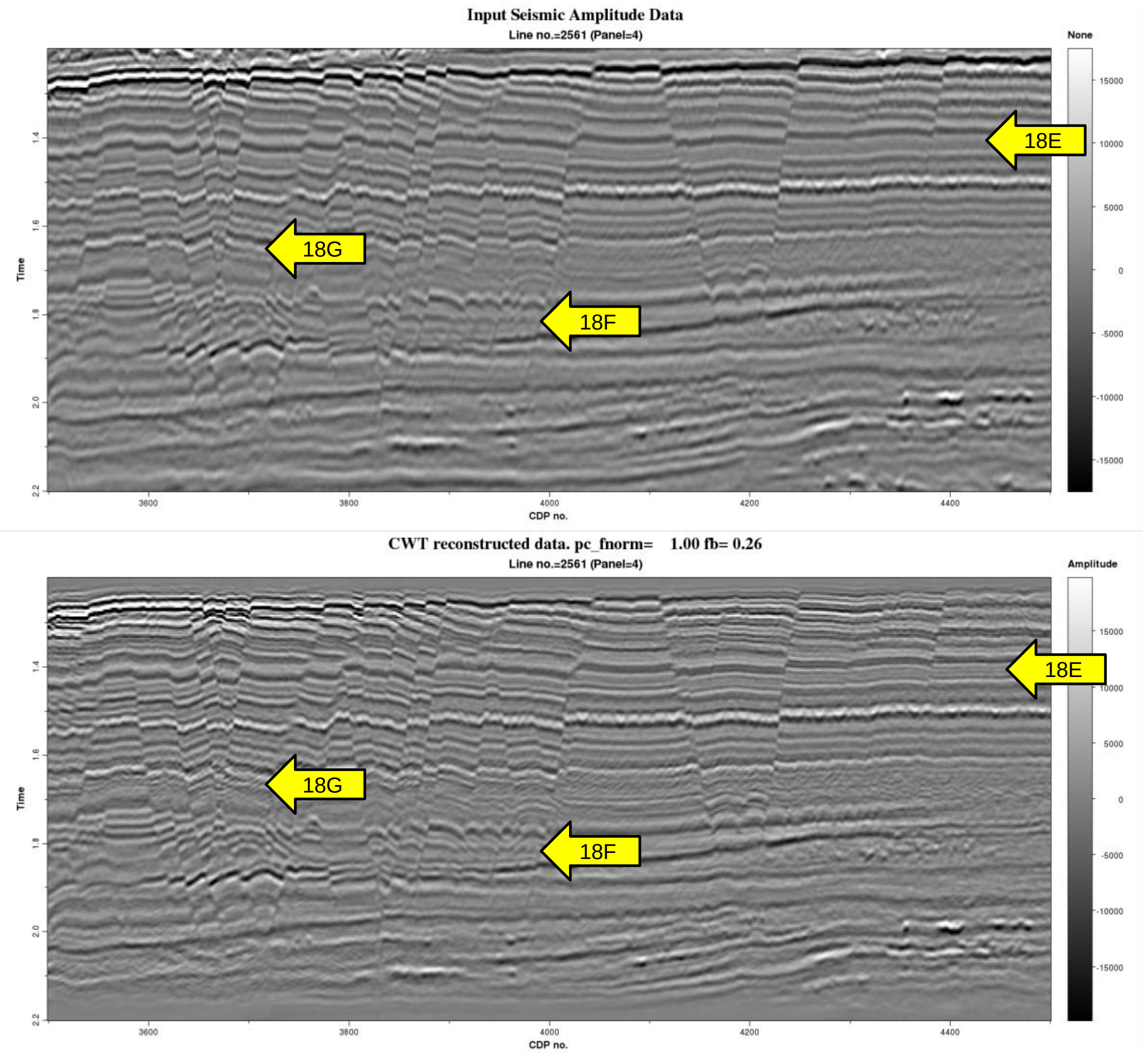


If you did not previously set your "AASPI default parameters" make sure you put in reasonable spectral components (18B). For this example, we start at 5 Hz and compute components up to 100 Hz at 5 Hz increments. For depth-migrated data, these values mays start at 2 cycles/kft, go to 10 cycles/kft, at 0.25 cycles/kft increments. When you go back to your office, rerun this algorithm with the spectral magnitude (18C), phase, and voice components turned on. On a laptop, these larger files may fill your disk drive, since they will generate a volume for each spectral component.

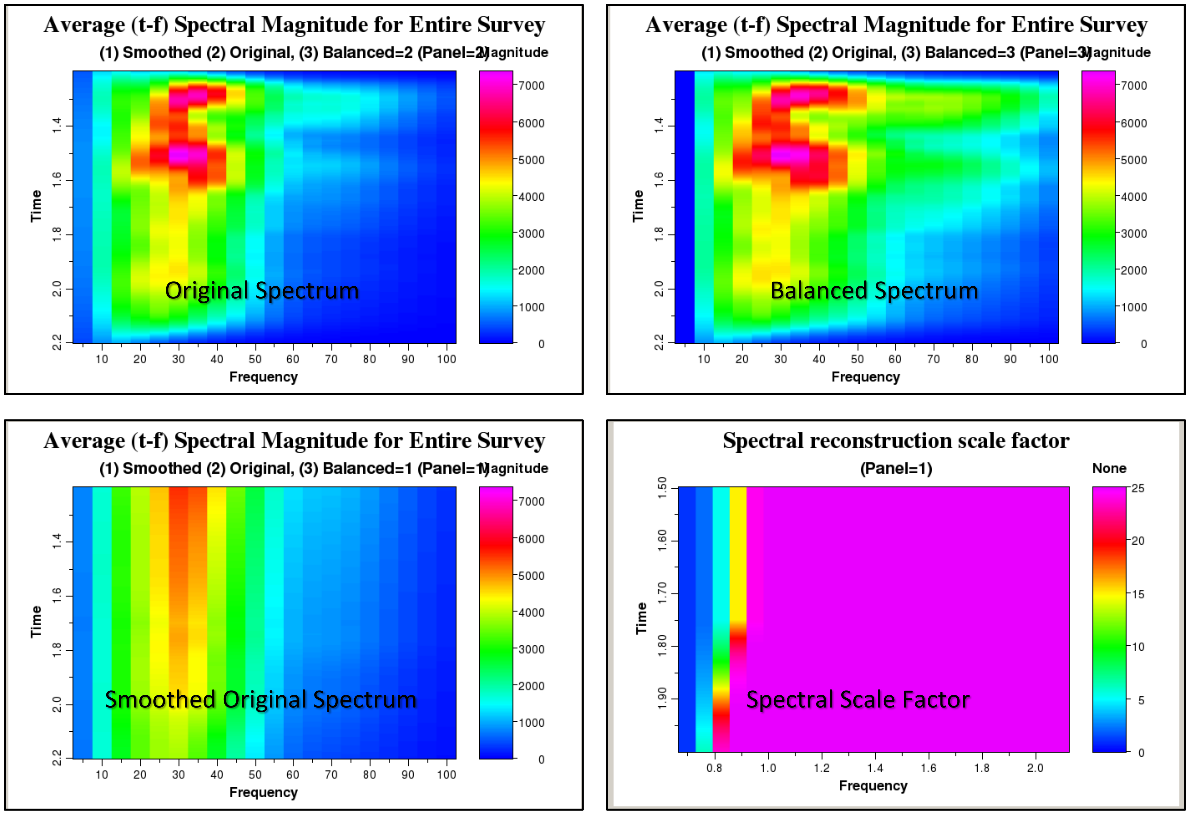
In spectral decomposition, the seismic data are decomposed into their spectral components. The spectral components can be expressed as the magnitude and phase, or as the voices. Adding the voices reconstructs the original data. Alternatively, if we choose to flatten (spectrally balance) or even "blue" the spectra, we can reconstruct a broader band, and thus higher resolution data volume. In the AASPI software, we simply call this the reconstructed data or d_recon_GSB_0.H.

In the GUI above, chose a 1% spectral balancing factor (18D). The resulting image, compared to the original looks like the figure below. The zone indicated by 18E brings out some subtle higher-frequency reflectors that previously were buried in other spectral components. If you are drilling a horizontal well, such subtle features can make your life much easier. In zone 18F we are able to discern rotated reflectors within the faulted area that were not previously well-defined. Spectral balancing can also enhance noise. Note the high-frequency cross-cutting artifacts at zone 18G which are probably to migration operator aliasing. A skilled interpreter can pick through these, but attribute calculations will think they are geology. We will address such cross-cutting artifacts when we discuss structure-oriented filtering.

Spectral balancing is a well-established practice in the processing shop. Another option in the AASPI software, bandwidth extension, is based on more rigorous assumptions about the underlying geology – specifically, that there are a discrete number of isolated (sparse spike) reflectors rather than a more continuous reflectivity response. To obtain greater confidence, a best practice is always to generate a synthetic from the well log and generate a wavelet from the original and spectrally balanced (or if you send your data out, for bandwidth extended) data. If the correlation of the seismic data with the well increases, you should feel quite confident that the spectral balancing or extension is valid. If it decreases, your balancing, bluing, or extension was too aggressive, and you should discard it.



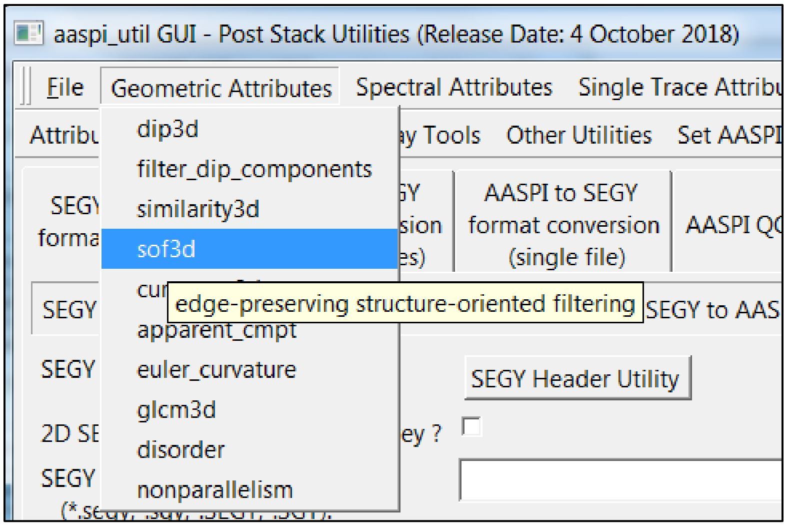
To see exactly what we have done, you will want to plot the files that begin with avg_spec_power and avg_spec_scale. I've arranged them to look like this:



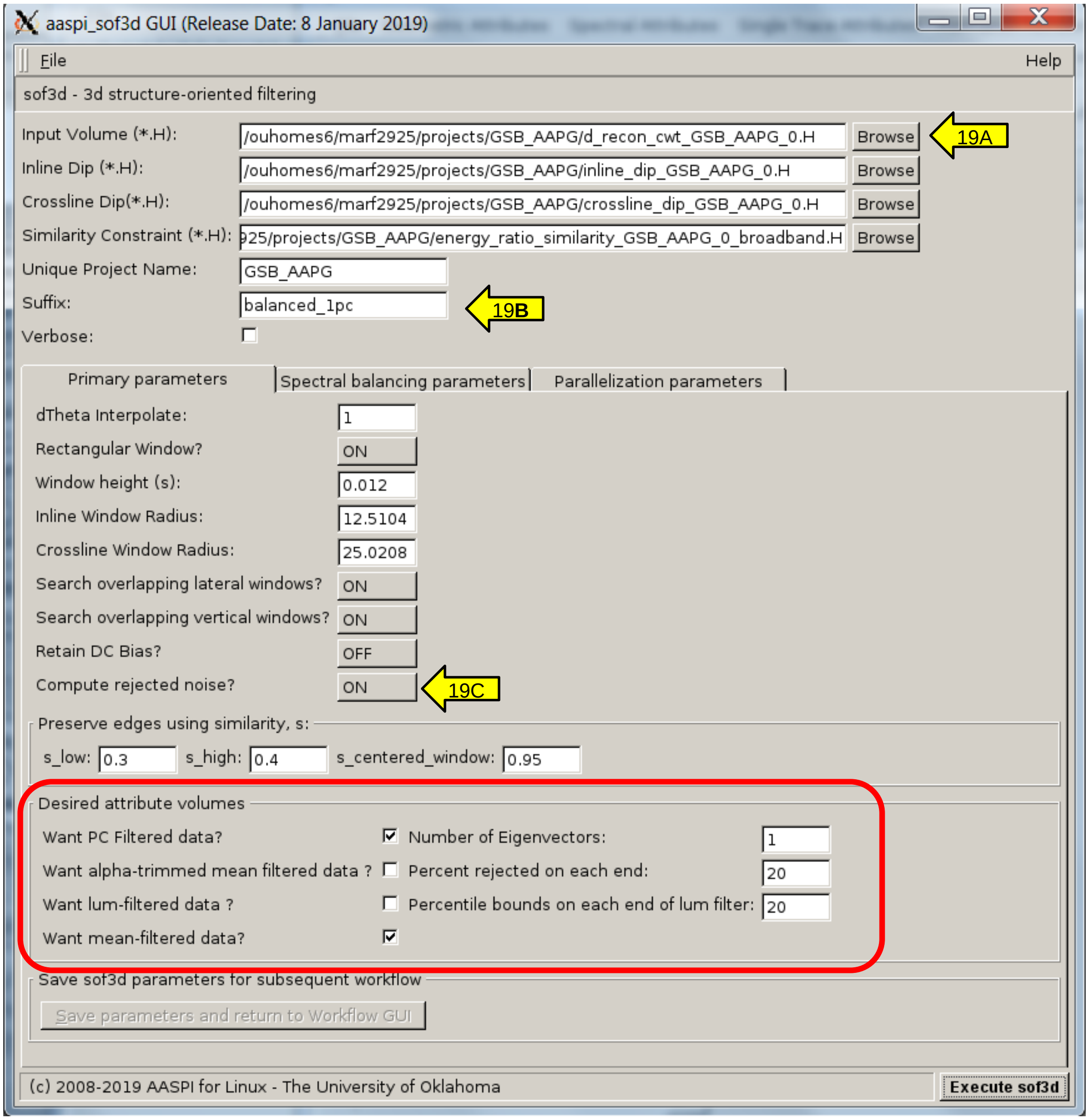
The upper left image is the average (smoothed over all line no. and cdp no.) time-frequency spectrum for the entire survey. The lower left image is a vertically smoothed ($\pm$0.5 s) version of the same spectrum. This average, vertically smoothed spectrum provides a scaling factor with a spectral balance factor of 1% (details in the lecture and documentation) shown on the lower right. This scaling factor is applied to the time frequency spectrum of each trace in the survey. The spatially averaged spectrum of the survey is shown on the upper right. Note how it is extended to both lower and higher frequencies.

Structure-oriented filtering using program sof3d

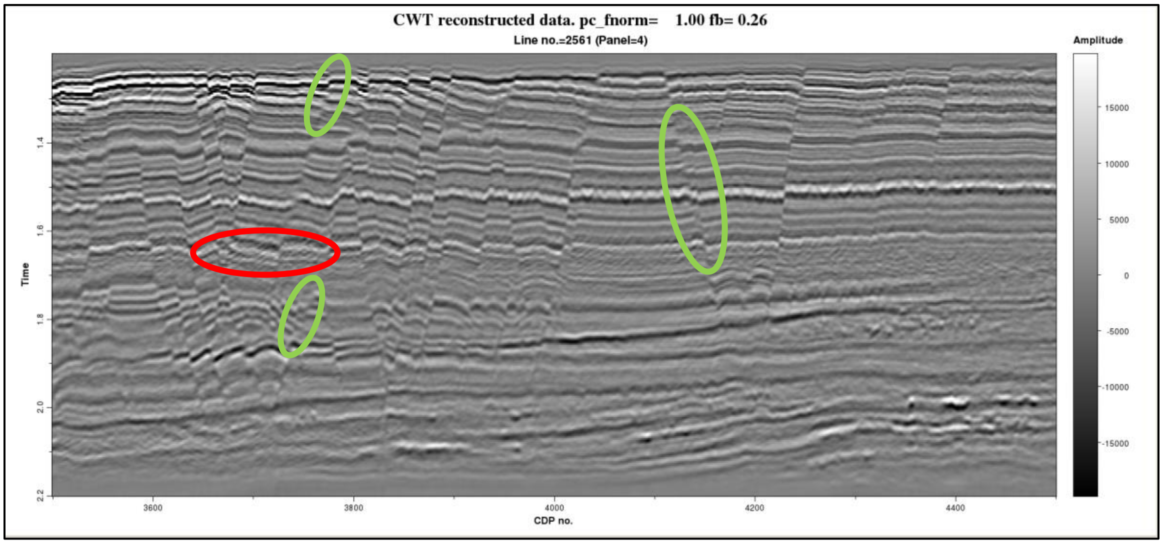
This will be our last exercise in this short introduction to seismic attributes. To run **sof3d**, go to *Volumetric Attributes → sof3d*

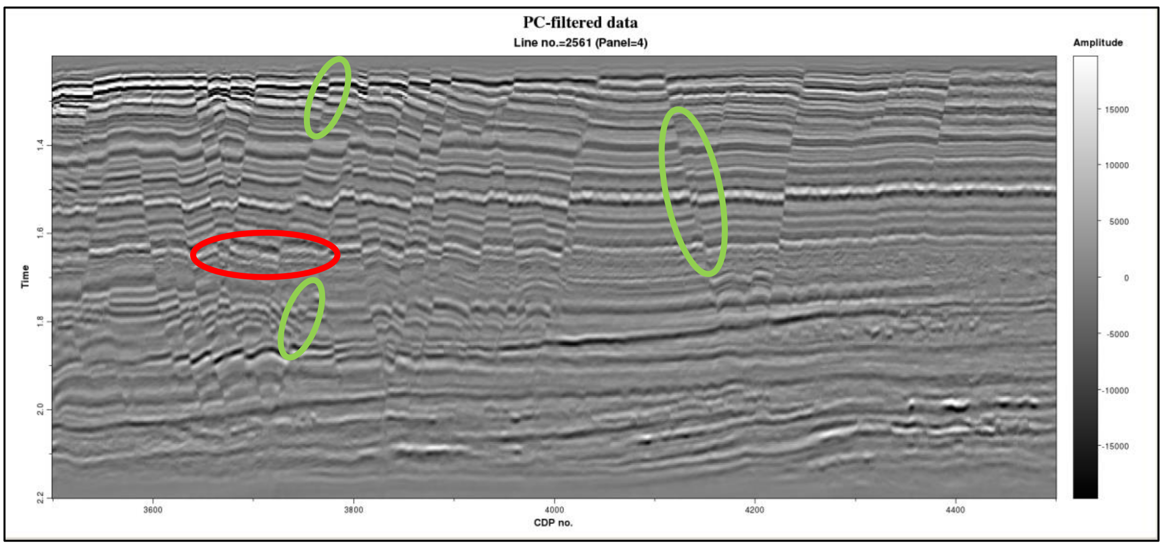


and fill out parameters on the following GUI. First, let's apply SOF to our previously spectrally balanced data volume to further improve it (19A). Type in a suffix (19B) that will differentiate this output result from one you may to run on the original seismic data volume. It is usually a good practice to examine the rejected noise to make sure you have not inadvertently damaged any signal (19C). Finally, choose the type of filter you want (red ellipse). Simple mean filters are the simplest and are common to most commercial software. A principal component filter (also called a Karhunun-Loeve or KL filter) provide the best preservation of amplitudes on good quality migrated data volumes. In contrast, if your data have noise spikes, as commonly occurs in filtering prestack migrated gathers, then you should choose either the alpha-trimmed mean or LUM nonlinear filters. Details on all these filters are found in the documentation under the *Help* tab.

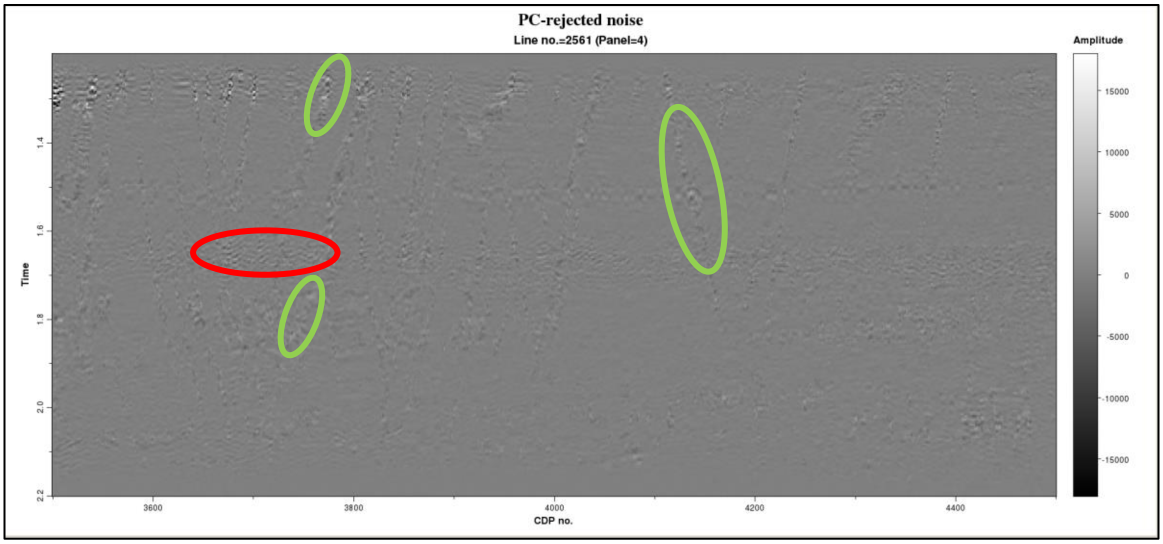


I obtain the following images, where the green ellipses indicate a slight improvement in the sharpness of the faults and the red ellipse a suppression of high-frequency cross-cutting noise due to migration operator aliasing:

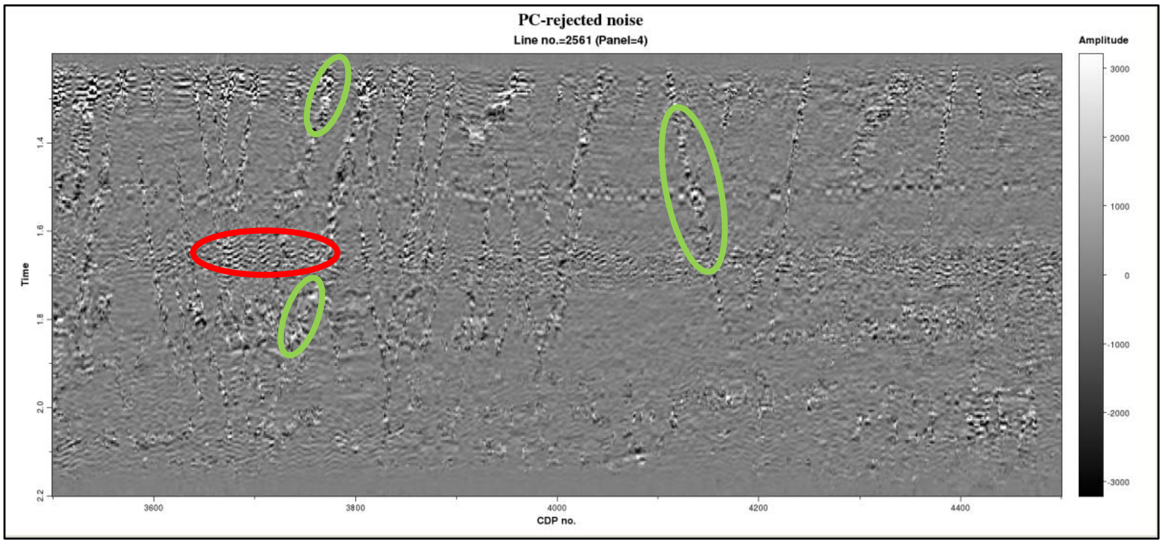




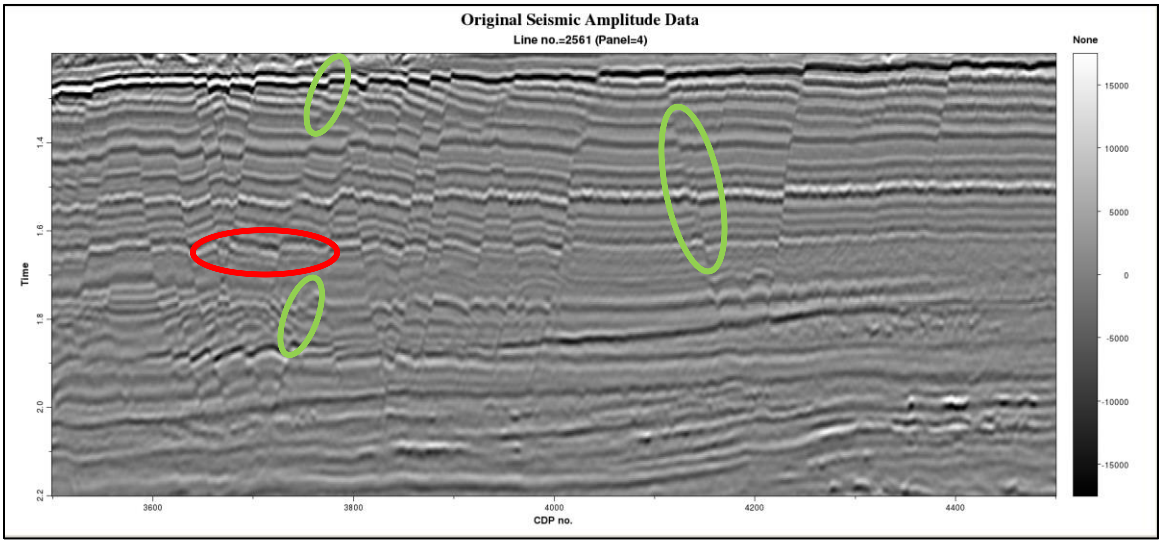
In general, it is a best practice to display the rejected noise at the same scale as the original data:



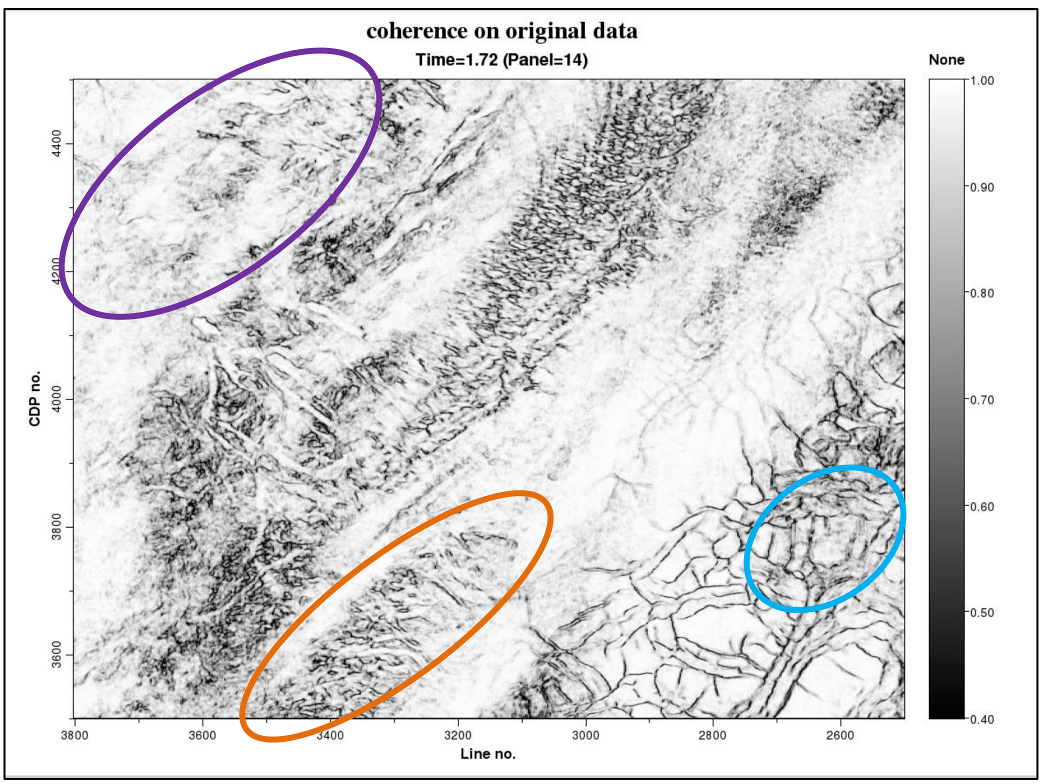
However, if you are reading this document on a hard copy, a statistically-balanced display better shows the kind of events that were rejected. In this image, few if any events appear to be continuous reflectors, with the exception of those (such as in the red ellipse) that cut across the stronger, true reflectors:



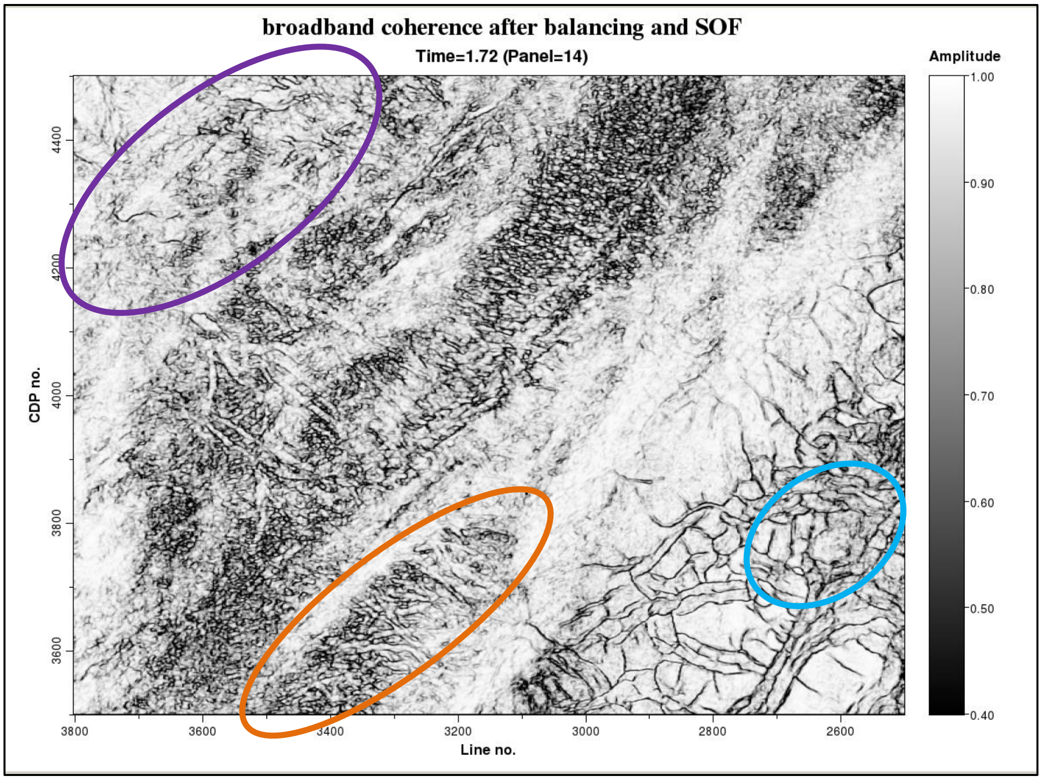
Let's compare this last image to original seismic data before spectral balancing and structure-oriented filtering.



Except for the top and bottom edges (where the CWT wavelets used in **spec_cwt** go outside the data boundaries) we've done a pretty nice job for a few hours work. Let's compare coherence computed from the original data



To that computed after spectral balancing and structure-oriented filtering:



Note that the channels are better delineated inside the red oval, while the faults edges are stronger and more continuous in the areas inside the cyan and purple ovals. Most important, this type of data conditioning can be done by an interpreter rather than by an outside seismic processing shop. The key requirement (as in conventional seismic processing) is to decide whether a given filter has improved or damaged the resolution of the geologic features of interest.