

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

	🗙 aaspi_util GUI - Post Stack Util	ties (Release Date: 8 January 2019)	
aaspi spec cwt GUI (Release Date: 8 January 2019)	∬ <u>E</u> ile Geometric Attributes	Spectral Attributes Single Trace Attrib	utes Formation Attributes Volumetric Classification Ir
File	Attribute Correlation Tool	spec_cmp earning Toolbox	Well Log Utilities Other Utilities Set AASPI Default Pa
Decompose the input seismic into time-freque Spectrally balance attributes and seismic amy Generate statistical measures of the time-free Compute phase residue attributes.	ncy spectral components usi Jitude data. Juency spectra.	11 GY tion and spectral balancing using a comple in spectral balancing using a comple in spectral prove [2] kxky_cwt kxky_cwt ktor to uspray was remomat attribute volu	x wavelet transform algorithm Prestack Utilities mes
Seismic Input (*.H): /ouhomes6/marf2925/p	rojects/Tui3d/d_mig_Tui3d_1.5-2.5s.H	Browse	
Unique Project Name: Tui3d	_		
Suffix: windowd	_		
Verbose:			
Compensate Spectra for Dip? Do Not Comper	nsate for Dip		
Inline Dip (* H)		iours o	
Crossline Dip (* 11).	<u>B</u>	rowse	
	<u></u>	owse	
Primary parameters Spatial Operati	on Window Temporal Operation Window Paralleliza	tion parameters	
Spectral Balancing Parameters	Reconstruction and Phase residue parameters		
Smoothing window (s) 0.5	CWT mother wavelet bandwidth (cycles/s)	0.260501	
Spectral balancing factor (%)	18D Bandwidth extension wavelet	0.5	
Bluing exponent: 0	forward transform bandwidth (cycles/s)		
Line and CDP decimation to quickly 5	Bandwidth extension wavelet inverse transform bandwidth (cycles/s)	1	
Ormsby filter applied to output	Interpolation factor	1	
f1: (cycles/s) 5	18B nstruction ridge_threshold (Percent):	1	
f2: (cycles/s) 10	Maximum number of iterations :	2	
f3: (cycles/s) 90	Taper in time (s)	0.1	
f4: (cycles/s) 120	Percentile excluded in spectral shape	0.15	
	Output spectral components		
	Use equally or exponentially spaced frequencie	S? Use equally spaced frequencies	
	Lowest output frequency, f_low (cycles/s):	5	
	Highest output frequency, f_high (cycles/s):	100	
	Frequency increment: (cycles/s)	5	
Results			
Want peak attributes?	Spectrally balance output?	ension output?	
Want spec mag cmpt 2 18C	□ Want spec phase cmpt? □ Want spec ve	vice cmpt?	
Want inverse CWT reconstructed data?	Want WTMML residual data? Want spectra	Ridges?	
Want spectral shape attributes?	Want phase residue attributes?		
Output component file format:			
C Multiple files - one per frequency compo	onent		
• A single hypercube file - with frequency	as axis z		
(c) 2008-2019 AASPI for Linux - The Universit	y of Oklahoma		Execute spec_cwt

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 (± 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* \rightarrow *sof3d*

aaspi_util GUI - Post Stack Utilities (Release Date: 4 October 2018)							
<u> </u>	Geometric Attributes S	ectral Attributes Single Trace Attril					
Attribu	dip3d	y Tools Other Utilities Set AAS					
SEG)	filter_dip_components similarity3d	Y AASPI to SEGY					
forma	sof3d	es) (single file)					
SEGY	curedge-preserving structure-oriented filtering SEGY to AAS apparent_cmpt						
SEGY	euler_curvature	SEGY Header Utility					
2D SE	glcm3d disorder	ey ?					
SEGY (*.se	nonparallelism						

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.

X aaspi_sof3d GUI (Relea	se Date: 8 January 2019)	X
∬ <u>F</u> ile		Help
sof3d - 3d structure-orient	ed filtering	
Input Volume (*.H):	/ouhomes6/marf2925/projects/GSB_AAPG/d_recon_cwt_GSB_AAPG_0.H Browse	
Inline Dip (*.H):	/ouhomes6/marf2925/projects/GSB_AAPG/inline_dip_GSB_AAPG_0.H Browse	
Crossline Dip(*.H):	/ouhomes6/marf2925/projects/GSB_AAPG/crossline_dip_GSB_AAPG_0.H Browse	
Similarity Constraint (*.H):	25/projects/GSB_AAPG/energy_ratio_similarity_GSB_AAPG_0_broadband.H Browse	
Unique Project Name:	GSB_AAPG	
Suffix:	balanced_1pc	
Verbose:		
Primary parameters	Spectral balancing parameters Parallelization parameters	
dTheta Interpolate:	1	
Rectangular Window?	ON	
Window height (s):	0.012	
Inline Window Radius:	12.5104	
Crossline Window Radius:	25.0208	
Search overlapping later	al windows? ON	
Search overlapping vertic	cal windows? ON	
Retain DC Bias?	OFF	
Compute rejected noise?		
Preserve edges using sir	nilarity, s:	
s_low: 0.3 s_high	1: 0.4 s_centered_window: 0.95	
Desired attribute volume	295	
Want PC Filtered data?	☑ Number of Eigenvectors:	
Want alpha-trimmed me	ean filtered data ? 🗖 Percent rejected on each end: 🛛 🛛 🛛 🛛	
Want lum-filtered data ?	Percentile bounds on each end of lum filter: 20	
Want mean-filtered data	۲ ۲ ۲.	
Save sof3d parameters	for subsequent workflow	
Save parameters and	return to Workflow GUI	
(c) 2008-2019 AASPI for L	inux - The University of Oklahoma Execute	sof3d

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 structureoriented 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:

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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.