CROSS-CORRELATING SPECTRAL COMPONENTS – PROGRAM spectral_probe

Spectral_probe computation flow chart

There is only one input file to program **spectral_probe** and a suite of crosscorrelation (and optionally data misfit) files. At present, the length of each sine and cosine operator is *exactly* one period, thereby avoiding ambiguous edge effects. Typical output will consist of cross-correlating the seismic data with periods of 10, 20, 30, and 40 ms.

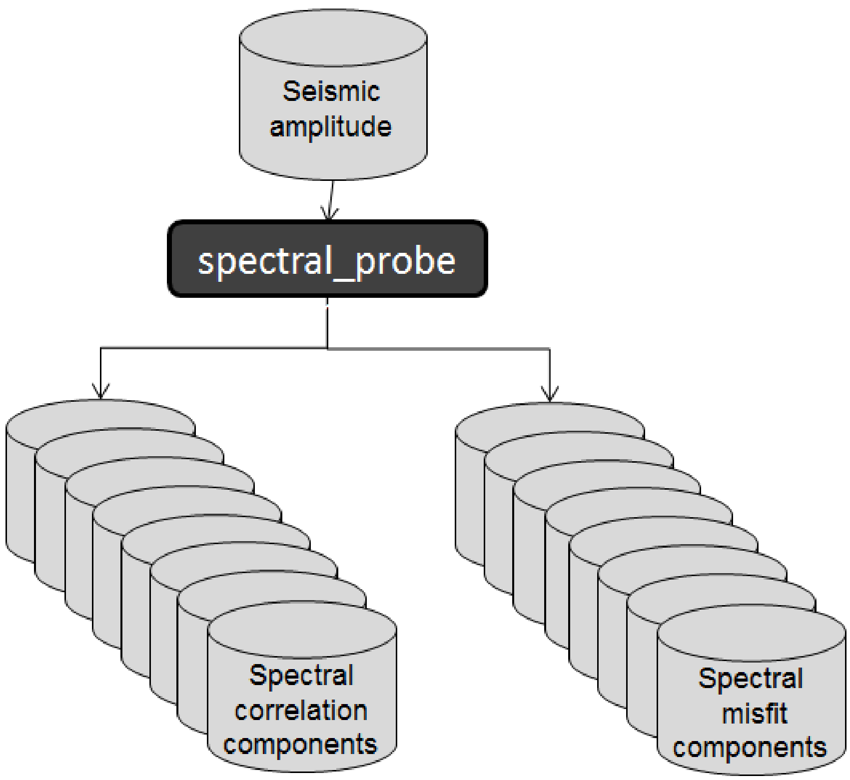
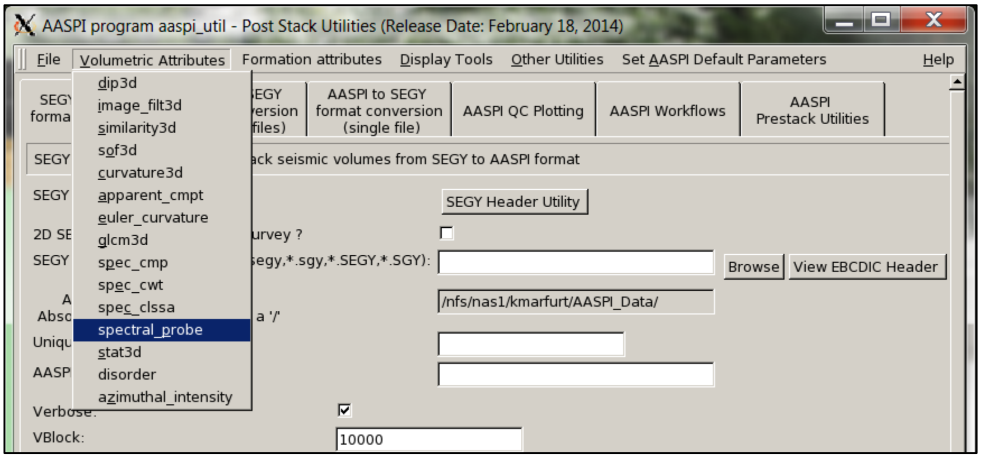


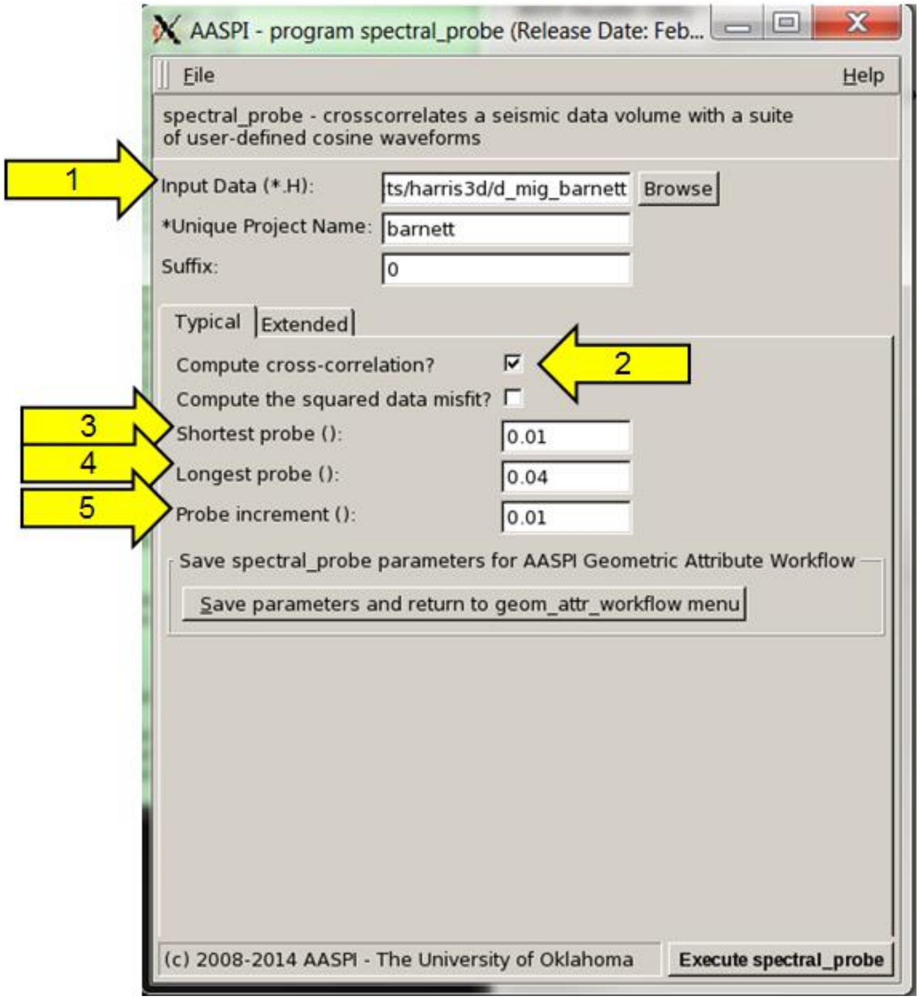
Figure 1. The flow chart for program **spectral_probe** – normalized crosscorrelation of spectral basis functions with the seismic amplitude data

Computing spectral components

To begin, click the *Volumetric Attributes* tab in the **aaspi_util** window and select the program **spectral_probe**:



Program **spectral_probe** generates normalized cross-correlation coefficients with the seismic data. The following window appears:



First, enter the (1) the name of the *Seismic Input (*.H)* file you wish to probe, as well as a *Unique Project Name* and *Suffix* as you have done for other AASPI programs. Normally, you will want to (2) generate cross-correlation coefficients. Gao (2014) also discusses the value of data misfit. Enter (3) the period of the minimum period and (4) the period of the longest probe, and (5) the probe increment. In this example, the first probe will be of length 0.01 s (frequency of 100 Hz) while the last of four probes will have a length of 0.04 s (frequency of 25 Hz).

Cross-Correlation, Spectral Decomposition, and Normalized Cross-Correlation

Cross-correlation of the seismic data with a suite of sines, cosines, or wavelets forms the basis of all spectral decomposition algorithms. If at a given location there is a high amplitude 50 Hz component in the seismic trace, there will be a correspondingly high cross-correlation coefficient. In contrast, if there is a low amplitude 50 Hz component in the seismic trace, there will be a low cross-correlation coefficient. These correlation coefficients form the spectral components of the data.

The concept of spectral_probe is somewhat different. Originally proposed by Gao (2014), one generates the normalized cross-correlation coefficient between a seismic wavelet, *w(t)*, and the seismic amplitude, *d(t):*

$$\rho(t)=\frac{\sum_{j=-J}^{+J} w(t-j\Delta t)d(t-j\Delta t)}{\left\{\sum_{j=-J}^{+J}\left[w(t-j\Delta t)\right]^2\right\}^{1/2}\left\{\sum_{j=-J}^{+J}\left[d(t-j\Delta t)\right]^2\right\}^{1/2}} . \qquad \text{(A1)}$$

If we set $w(t)=\cos(2\pi ft)$ or cosines, *d(t)* to be the seismic trace, and choose the correlation range $2J\Delta t=1/f$ (exactly one period) then the equation A1 simplifies to become

$$\rho(t)=\frac{\sum_{j=-J}^{+J}\cos\left[2\pi\left(t-j\Delta t\right)\right]d(t-j\Delta t)}{\left\{\sum_{j=-J}^{+J}\left[d(t-j\Delta t)\right]^2\right\}^{1/2}} . \qquad \text{(A2)}$$

The value of the normalized cross-correlation coefficient, ρ(t) will always fall between -1.0 and +1.0 . In a mathematically loose sense, the result approximates a spectral "voice" that has been subjected to a short window automatic gain control.

Example 1

The following example comes from the Mississippi Lime of northern Oklahoma. A suite of 11 probes were run, ranging from 0.010 to 0.100 s in length. Note the improved clarity of the faults seen using the 0.070 and 0.050 s probes in comparison to the original broad-band data and 0.010 s probe. This visual observation is confirmed by computing coherence using program **similarity3d** on each of the 12 volumes.

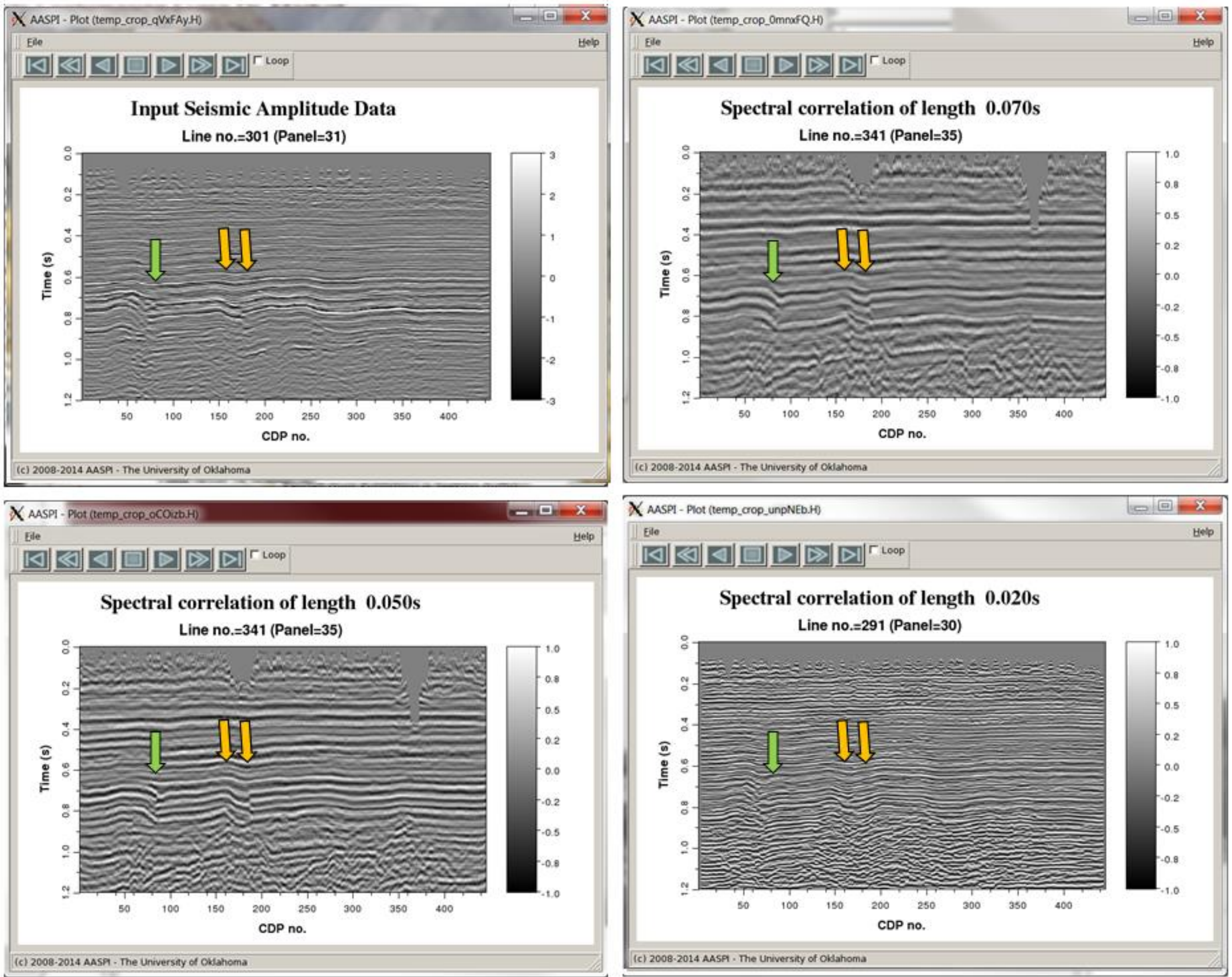


Figure.2. Vertical slices through (a) original broadband seismic amplitude data and spectral probes of period (b) 0.070 s or 14 Hz, (c) 0.050 s or 20 Hz, and (d) 0.020 s or 50 Hz. The strike slip faults indicated by the orange and green arrows shows up more clearly in the 70 ms and 50 ms probes and less clearly in the original broadband data and the 20 ms probe. Faults cut the Mississippi Lime in Kay Co., OK, near the Nemaha Ridge.

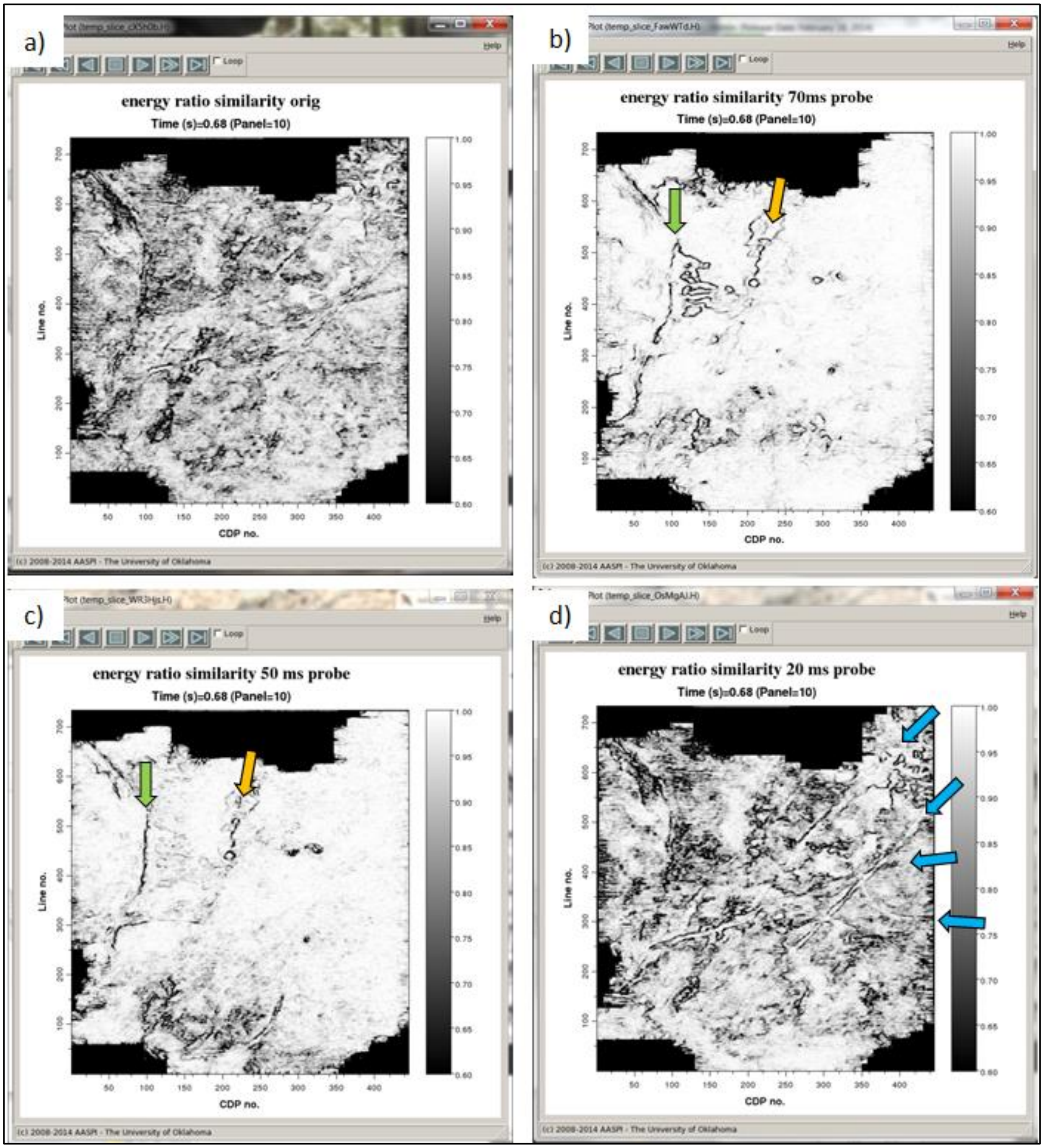


Figure 3. Times slices at t=0.68 s at the approximate level of the Mississippi Lime through eigenstructure coherence images computed from (a) original broadband seismic amplitude data and spectral probes of period (b) 0.070 s or 14 Hz, (c) 0.050 s or 20 Hz, and (d) 0.020 s or 50 Hz. All coherence computations were generated using a 5 trace, ±10 ms analysis window along the same structural dip estimate. The large fault (green arrow) and small graben (orange arrow) are more clearly illuminated

by the 70 ms and 50 ms probes while the stratigraphic features (blue arrows) are more clearly illuminated by the 20 ms probe.

References

Gao, D., 2014, Constant-phase waveform model regression for seismic structure characterization: Methodologies with case studies: Geophysics (in press).