3D WINDOW-BASED STATISTICS – PROGRAM stat3d

Contents

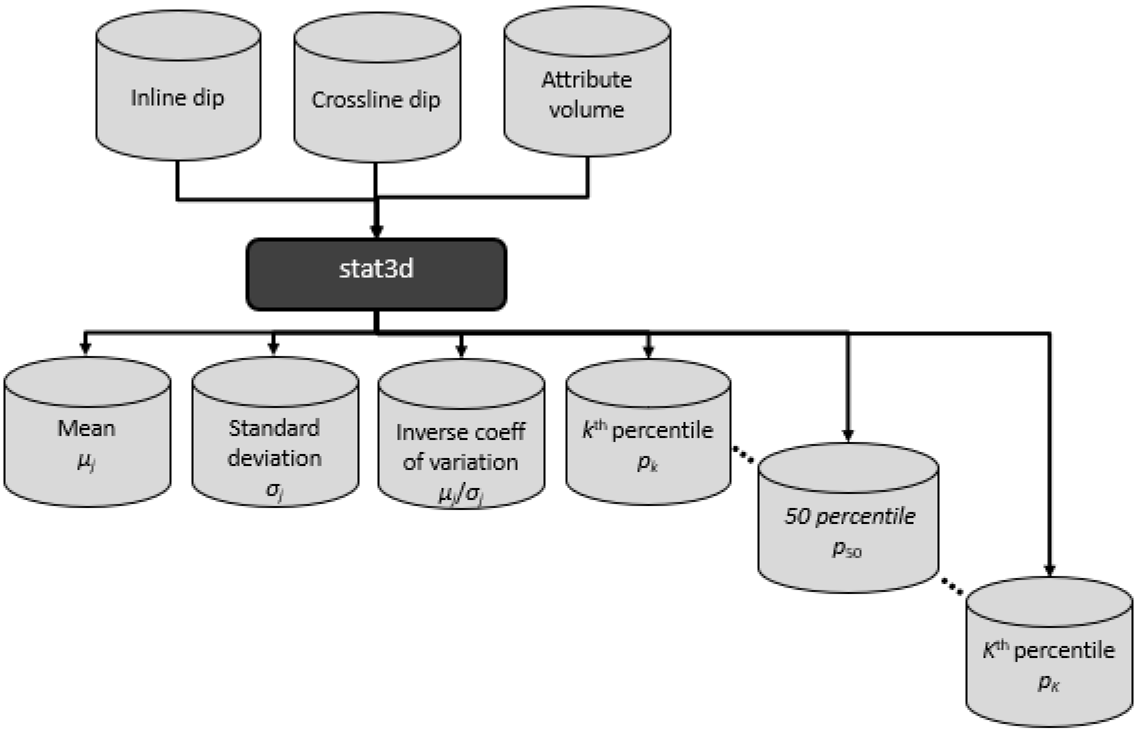
Overview 1
Computation flow chart 1
Output file naming convention 2
AASPI Implementation 3
Theory: Basic Statistics...5
The mean 5
The standard deviation 5
The inverse of the coefficient of variation 5
The median 5
Percentiles 5
Resulting statistics volumes from program stat3d 6
References 9

Overview

Program **stat3d** computes the mean, median, standard deviation, inverse of the coefficient of variation, and user-defined percentiles within structurally-oriented windows. These values can be used as an attribute by themselves, or provided as input to subsequent analysis, such as to programs **disorder** and **kuwahara3d**.

Computation flow chart

To compute statistical attributes along structural dip, the inline and crossline dip components of the seismic amplitude data need to be computed first, via program **dip3d**. Other attributes are also precomputed.



Output file naming convention

Program **stat3d** always generates the two output files:

Output file description	File name syntax
Program log information	stat3d_*unique_project_name_suffix*.log
Program error/completion information	stat3d_*unique_project_name_suffix*.err

where the values in red are defined by the program GUI. The errors we anticipated will be written to the *.err file and be displayed in a pop-up window upon program termination. These errors, much of the input information, a description of intermediate variables, and any software trace-back errors will be contained in the *.log file.

If desired, program **stat3d** will also generate the following output files:

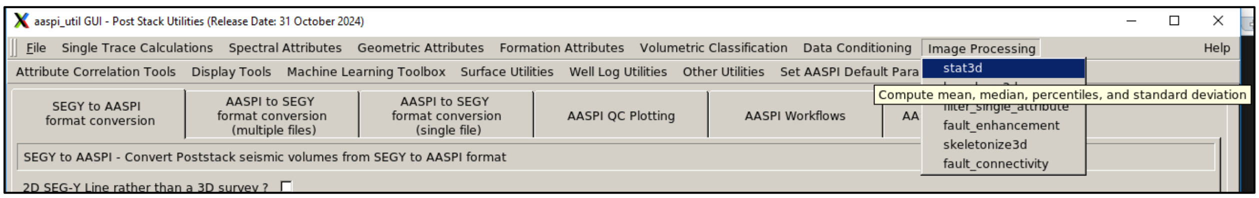
Output file description	File name syntax
Mean value in the window	mean_*attribute_name_unique_project_name_suffix*.H
Standard deviation in the window	sigma_*attribute_name_unique_project_name_suffix*.H
Inverse coefficient of variation	Inv_coeff_variation_*attribute_name_unique_project_name_suffix*.H

k^{th} percentile in the window	p*k_ attribute_name_unique_project_name_p*.H

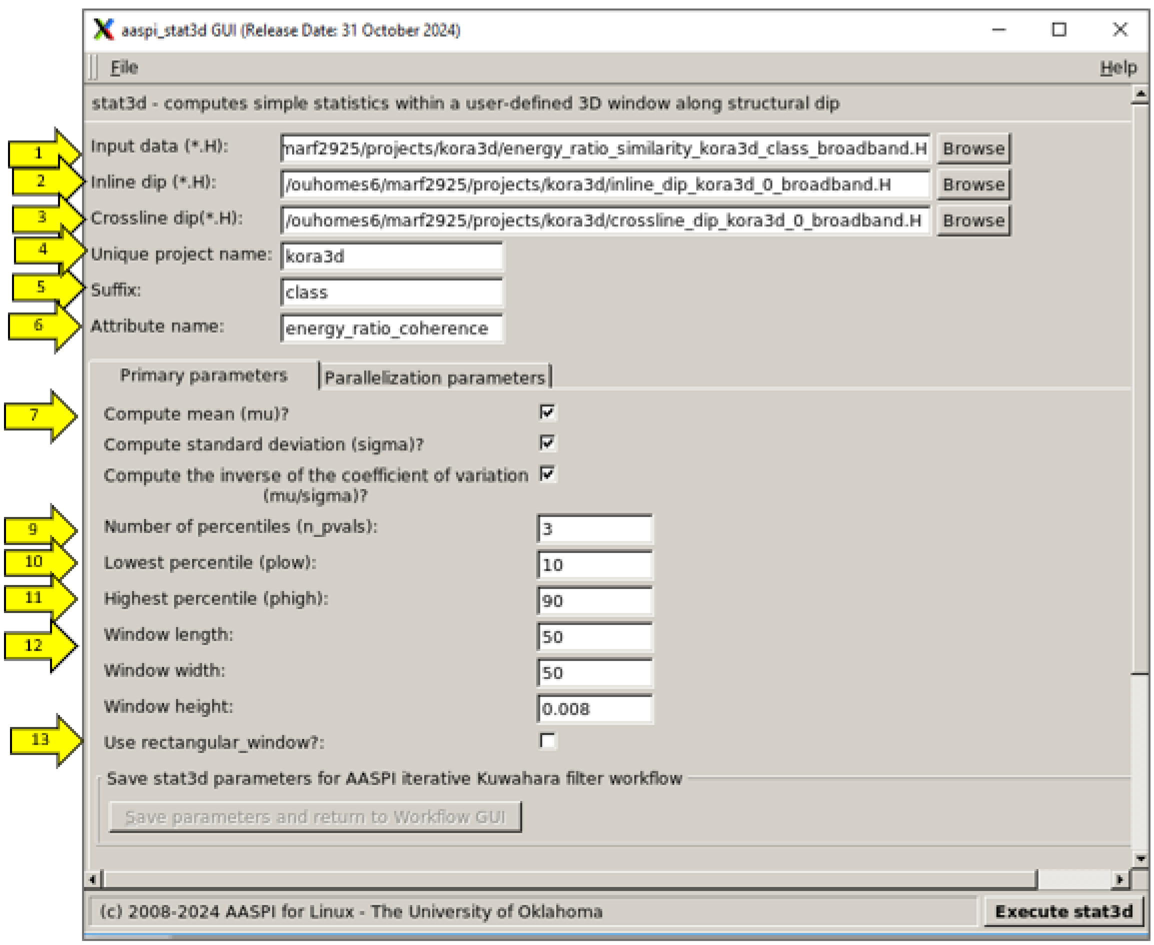
where the integer value *k* ranges from 1 to 99 and the p50 output volume is the median filtered data which will be called p50_ *attribute_name_unique_project_name_p*.H .

AASPI Implementation

You will find program **stat3d** under the AASPI *Image Processing* tab:



By clicking the program **stat3d**, the following GUI appears:



The input parameters are self-explanatory. (1) Enter the name of the *Input data* (i.e., attribute) you wish to filter. In this example, I've chosen energy-ratio coherence. Then because the filtering is structure-oriented, enter the (2) *inline* and (3) *crossline dip* components for this survey. As with almost all AASPI programs, enter a (4) *Unique project name* and (5) *Suffix*. The output names will start with the type of statistic defined under (7) which include the mean, standard deviation, inverse of the coefficient of variation, and three or more percentile volumes (in this example, p10, p50 (the median), and p90). The (6) *Attribute name*, (4) *Unique project name*, and (5) *Suffix* will be concatenated with the filter name to generate the various output volume names. In this example, the median filtered volume will be called *p5_energy_ratio_coherence_kora3d_class.H* . Next, enter the (9) *Number of percentiles* desired and the range of the (10) *Lowest percentile, pLow,* and the (11) *Highest percentile*, p*High*. The final parameters defined the size of the Kuwahara window used. In this example the voxels are 12.5 m × 25 m × 0.004 s. In this example, I've chosen a larger window to generate more robust statistics of 50 m × 50 m × 0.008 s. All windows have vertical sides with tops and bottoms that are aligned with structure. In this example, I've chosen an oblique (13) rectangular prism rather than an oblique ellipsoidal analysis window.

Theory: Basic Statistics

Let's assume we have *J* voxels that fall within a 2D or 3D analysis window along structural dip. There are several linear and nonlinear filters that can be applied.

The mean

The mean filter is the best-known and simplest random-noise suppression filter and forms the basis of most seismic stacking algorithms. On maps, the mean filter is a low-pass filter that typically is implemented as a running-window-average filter. The output-data value is the average of all the samples that fall within a centered analysis window. The window size is usually an odd number, such as three by three or five by five, and may be either rectangular or elliptical.

The mean filter is the simplest, where the mean μ of *J* samples d_j is defined as:

$$\mu = \frac{1}{J}\sum_{j=1}^{J} d_j \,. \tag{1}$$

The mean filter is a smoothing filter and may not only smooth across faults but smooth in erroneous spikes into the output.

The standard deviation

The standard deviation is given by

$$\sigma = \left[\frac{1}{J}\sum_{j=1}^{J}\left(d_j - \mu\right)^2\right] \tag{2}$$

The inverse of the coefficient of variation

The coefficient of variation scales the standard deviation σ by it's mean μ, giving $V = \frac{\sigma}{\mu}$. This metric can be unstable if the mean μ is close to zero. A more robust measure is the inverse of the coefficient of variation

$$V^{-1} = \frac{\mu}{\sigma} \,. \tag{3}$$

The median

The median is one of the most widely used nonlinear techniques in signal and image processing and also is used routinely to filter VSP data. The median filter replaces each sample in a window of a seismic trace by the median of the samples that fall within the analysis window; in so doing it rejects outliers. The window size typically is an odd number (e.g., 3 ×3 × 3, or 5 × 5 × 5). The first step of the median filter is to sort the data vector, **d**, into a new vector **u** where $u_k \le u_{k+1}$:

$$\mathbf{u} = \mathrm{sort}\left\{d_1, d_2, \ldots, d_j, \ldots, d_{J-1}, d_J\right\}. \tag{4}$$

Then the median, *m*, is defined as:

$$m = u_{(J+1)/2} \,. \tag{5}$$

The median filter is an edge-preserving filter and will preserve changes in dips across faults. It also rejects erroneous spikes in the input data.

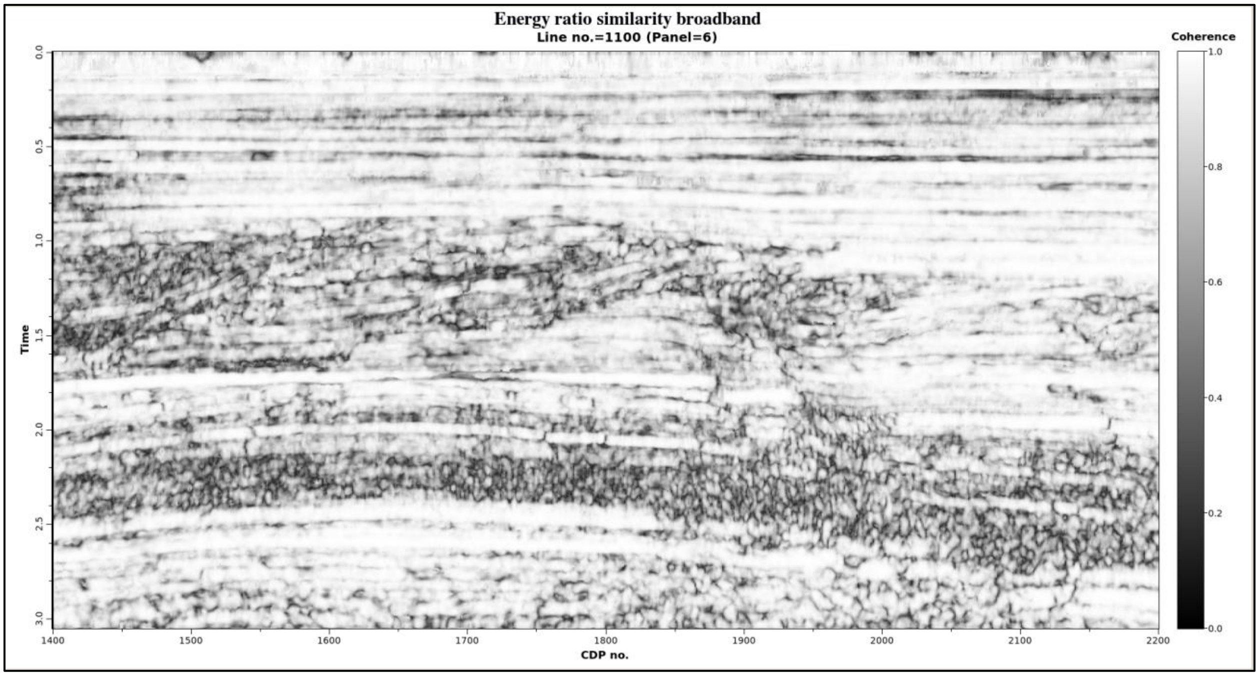
Percentiles

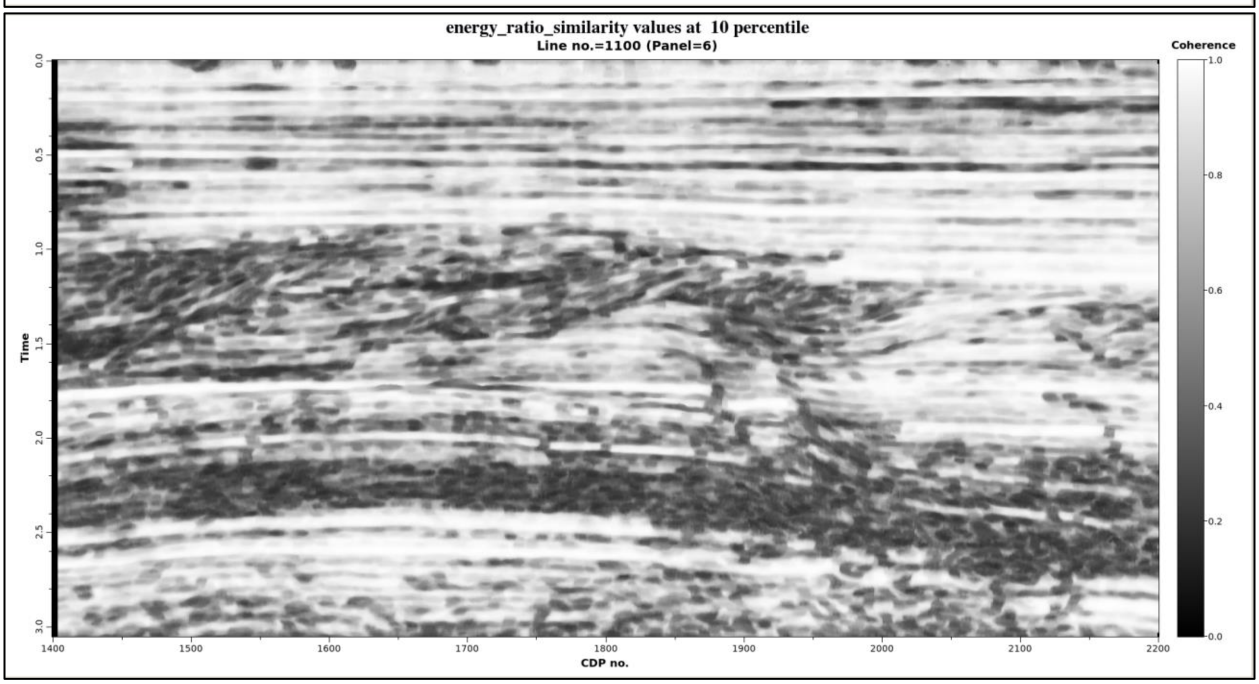
The pth percentile is simply the value u_k in equation 2 where

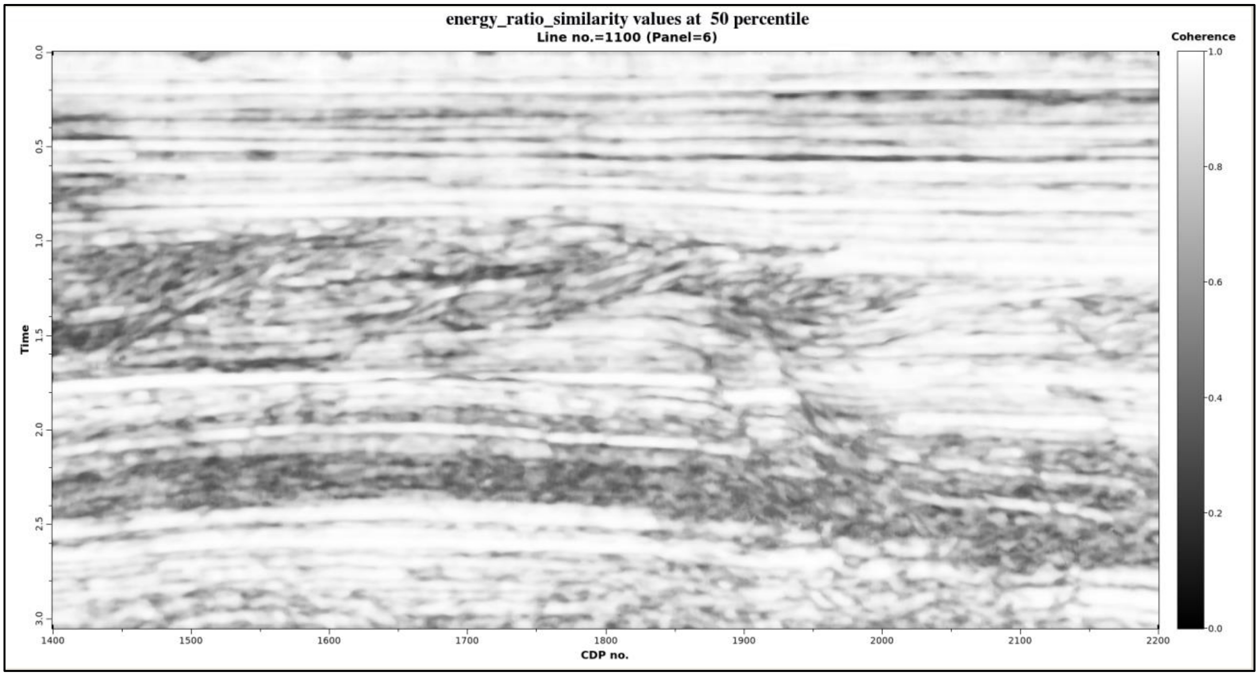
$$k = \mathrm{NINT}\left[\frac{p}{100}(J-1)\right] + 1 \,. \tag{6}$$

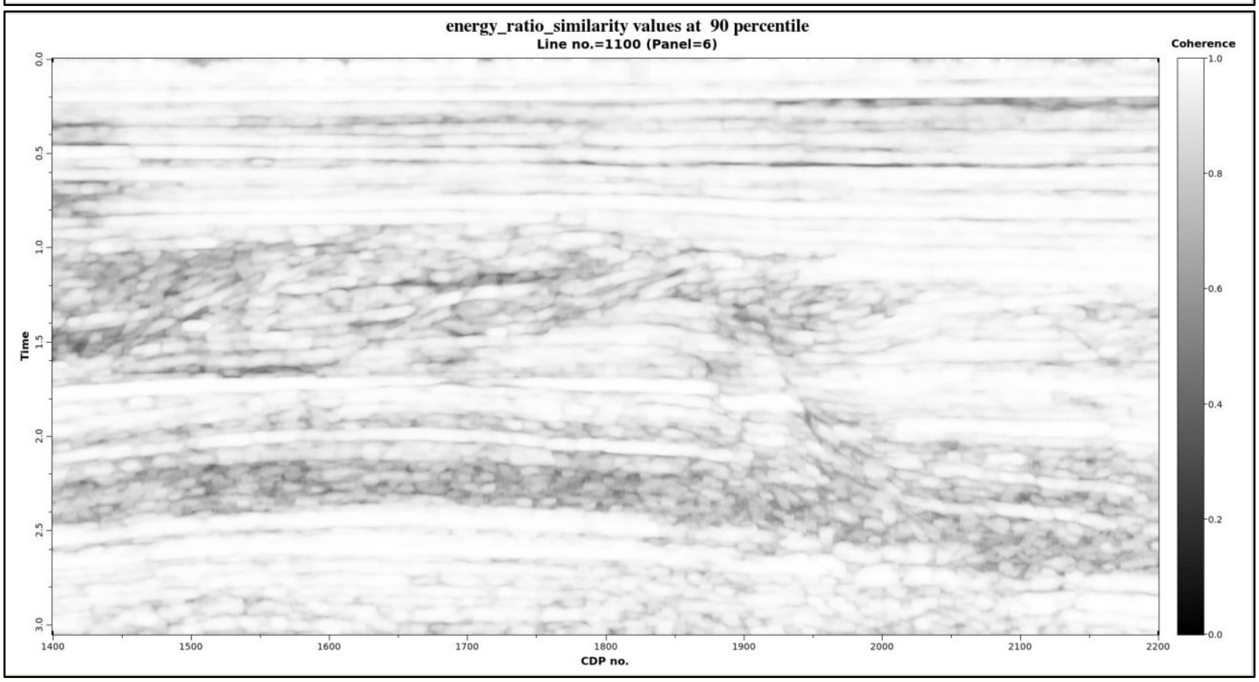
Resulting statistics volumes from program stat3d

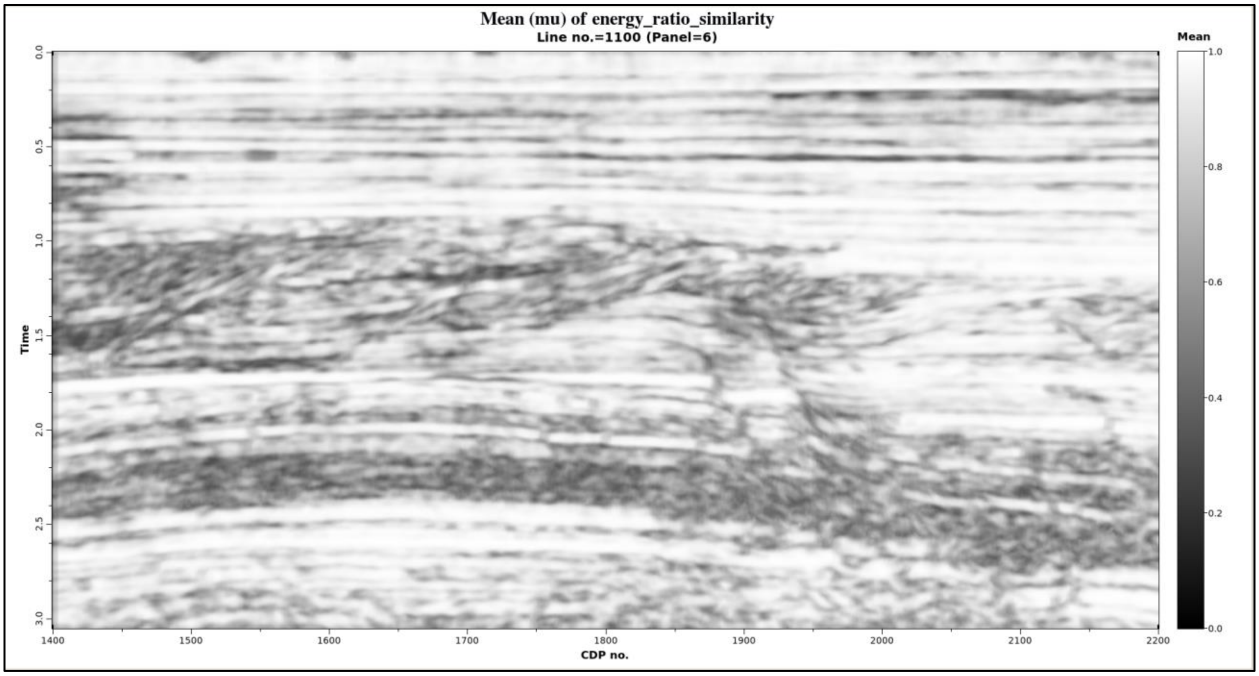
Let's start by displaying a vertical slice through the original coherence volume, followed by the p10, p50 (median!), p90, mean, standard deviation, and inverse coefficient of variation

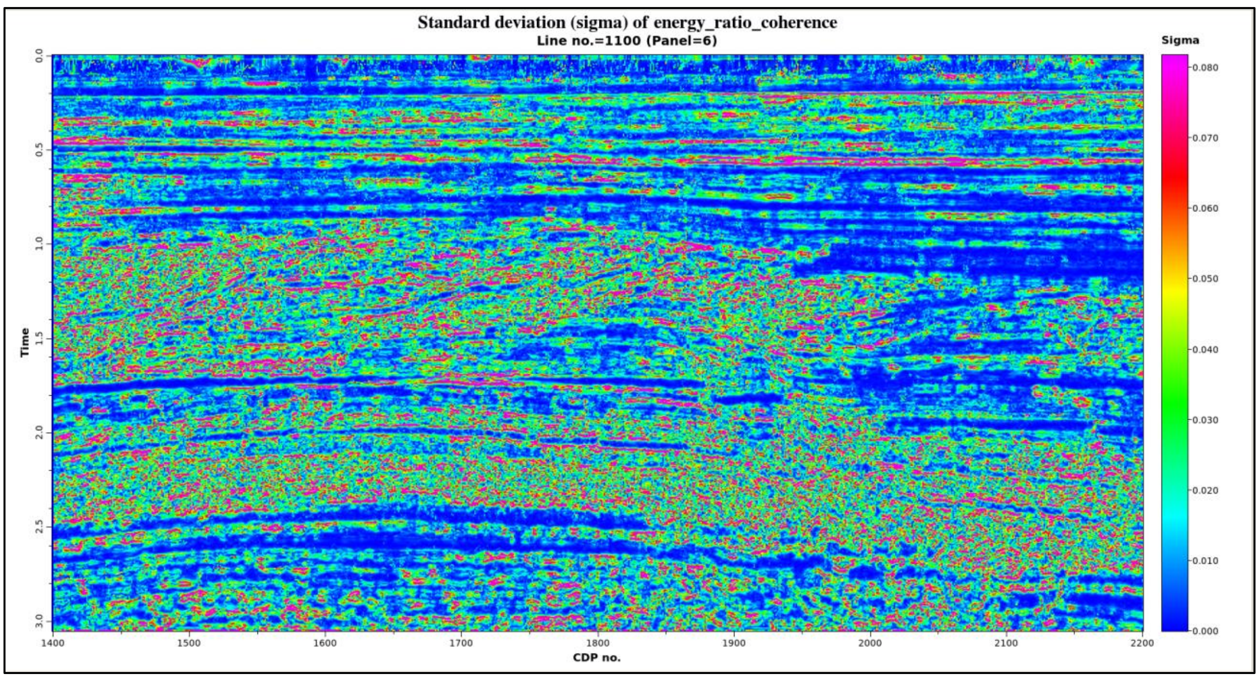


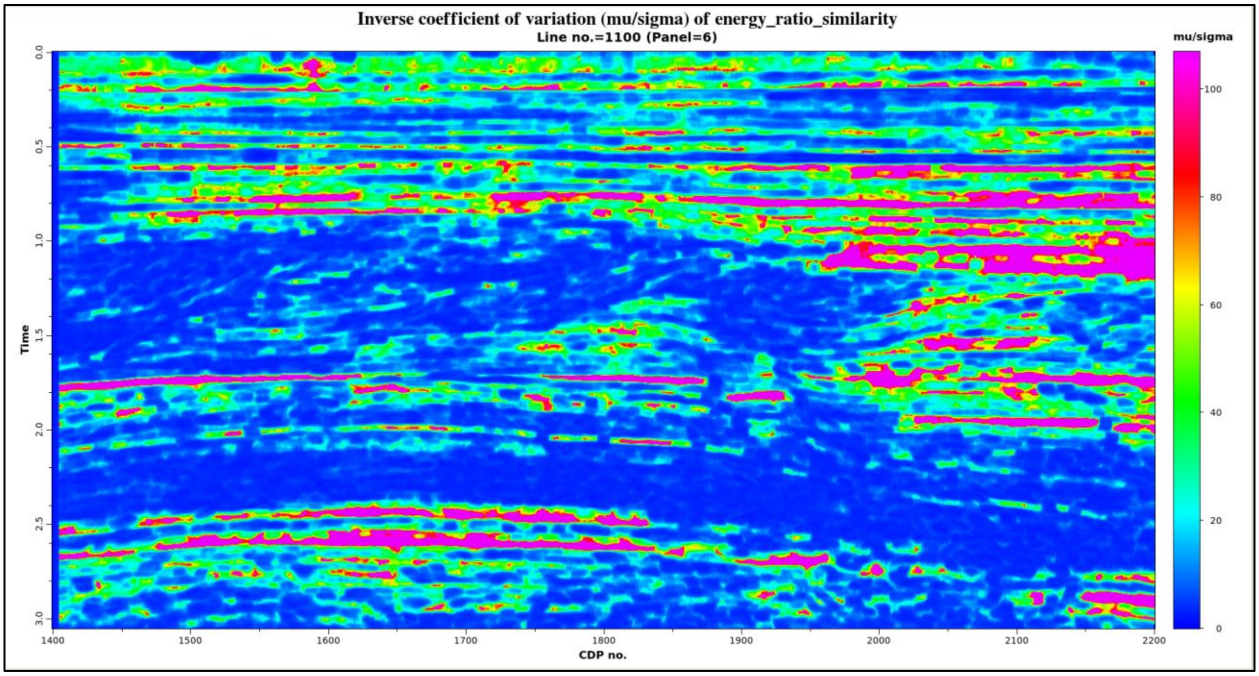



energy_ratio_similarity values at 50 percentile
Line no.=1100 (Panel=6)
Coherence
Time
CDP no.


energy_ratio_similarity values at 90 percentile
Line no.=1100 (Panel=6)
Coherence
Time
CDP no.


Mean (mu) of energy_ratio_similarity
Line no.=1100 (Panel=6)
Mean
Time
CDP no.


Standard deviation (sigma) of energy_ratio_coherence
Line no.=1100 (Panel=6)
Sigma
Time
CDP no.



In the last two examples, the values of the standard deviation and the inverse of the coefficient of variation have scaled between their 0 and 95th percentile.

References

Qi, J. T. Lin, T. Zhao, F. Li, and K. J. Marfurt, 2016, Semisupervised multiattribute seismic facies analysis: Interpretation, **4**, SB91-SB106.