AUTO

ParkSEIS

PS

User Guide

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Park Seismic

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1. Overview

Extraction of the fundamental-mode (M0) dispersion curve is a critical step during MASW analysis, the accuracy of which has a direct impact on the final velocity (Vs) profile. Up until now, it has been the only step in ParkSEIS (as with all other MASW analysis tools) that required the user's intervention to identify the corresponding energy pattern for the M0 trend. This step can be fairly straightforward if the trend is the only dominant energy pattern present in the dispersion image [also known as "overtone (OT)" image]. Or, as is more commonly the case, it can be a challenging task if the overtone record includes other trends created from multiple causes such as higher modes, ambient noise, energy segments arising from lateral variation of subsurface conditions, computational artifacts due to Gibb's phenomenon and boundary effects, body wave effects, etc.

As of this version of ParkSEIS, detection of the fundamental-mode (M0) dispersion trend is now handled through a fully automated process that works on various (theoretical and empirical) aspects of dispersion image data. The process is similar to a pattern recognition technique that is grounded in the theory of wavefield transformation that generates the overtone record. The actual technical implementation is linked to a significant number of empirical parameters that are properly calibrated for the condition of the original seismic field record as well as the corresponding overtone record. This empirical calibration has been made using several hundred field data sets acquired at sites of diverse subsurface conditions.

The detection of M0 trend is made through a comprehensive evaluation of the overtone record, which evaluates the following five (5) attributes of the record:

- **Pattern**: Recognition of the most dominant surface wave event is assessed in its spectral and phase velocity attributes. Then, the overall strength and continuity of the pattern is estimated from the surface wave dispersion perspectives.
- **Coherency**: Most major energy trends are identified and their relative coherencies are estimated.
- **Definition**: Major energy segments are selected and then evaluated for their strengths in comparison to those of the body wave segments.
- **Amplitude**: Major energy segments are selected and then evaluated for their energy levels with respect to the background noise level.
- **Energy**: An absolute amount of surface wave energy is estimated.

The detection process accounts for all of these attributes (with varying degrees of contribution). The key parameter, however, is the "Pattern" which is calculated first and then upon which other relative contributions are determined. The detected M0 trend is used to set a specific area (called the "Bound OT") in the original overtone image to which the subsequent process of the curve extraction should focus. This is similar to setting the (lower and upper) bounds along the visually identified M0 trend, which is the mode of operation during a manual process. A flowchart of the overall process is presented in Figure 1.
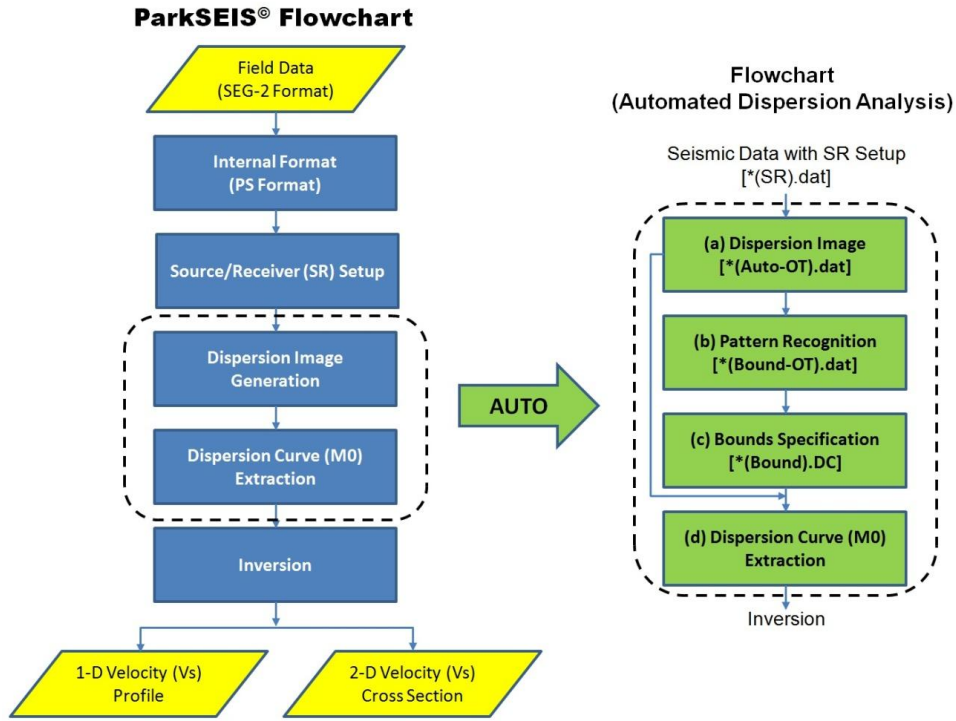
Figure 1. A general flowchart of the automatic detection algorithm (right) in reference to the flowchart of ParkSEIS (left).

To briefly explain each step in the flowchart:

(a) A seismic data set with field-geometry encoded [*(SR)*.dat] is used as an input to the 2D wavefield transformation. A dispersion image (overtone) data set [*(Auto-OT).dat] is produced from this process.

(b) Each overtone record is then evaluated by a pattern recognition method for the amount of signal wavefields (i.e., M0 surface waves) with respect to all other wavefields (i.e., for SN ratio). Then, a new set of overtone data [*(Bound-OT).dat] is prepared by applying proper signal-enhancing techniques to the original overtone records [*(Auto-OT).dat].

(c) A special type of dispersion curve [*(BoundDC).dc] is extracted from each record in this new data set. This curve contains information about detected M0 trend in the original overtone record [*(Auto-OT).dat].

(d) An M0 curve is extracted from each of the original overtone records [*(Auto-OT).dat] by using the special dispersion curve from (c) as a bound curve. All extracted curves are then saved and/or passed to the next inversion process to generate a (1D or 2D) velocity (Vs) profile.

To start the automatic process, select "AUTO" item from the main menu (yellow arrow), or select "AUTO" tab from the tool panel (green arrow) as illustrated below.
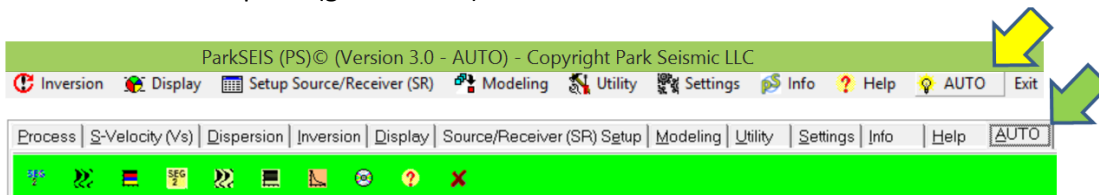
2. AUTO for 2D Velocity (Vs) Cross Section

This section describes the automatic process used to generate a 2D velocity (Vs) cross section at the end [*(2DVs).txt]. It can start from (2.1) original seismic field data in SEG-2 format that may or may not have the source/receiver (SR) setup encoded, (2.2) a seismic field data set previously prepared that has SR setup encoded [*(SR)*.dat], or (2.3) an overtone record data set previously prepared [*(Auto-OT).dat]. If the original SEG-2 seismic data set does not have a proper SR setup encoded, then you have to go through the source/receiver (SR) setup process first before the automatic process takes place.

2.1 From Field Seismic Files in SEG-2 Format

From the main menu, select items as shown below:
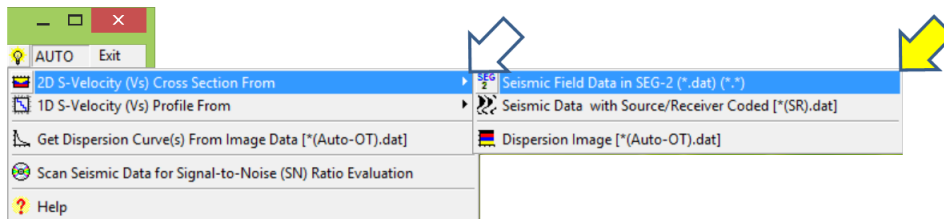
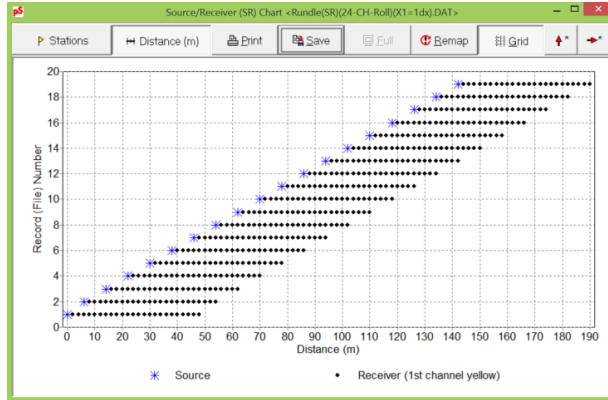Or, from the tool panel, select the button as shown below:

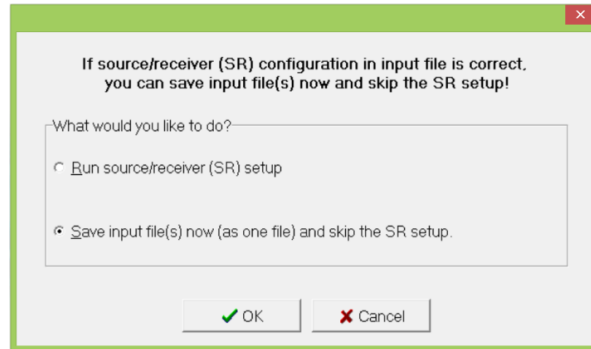Select multiple seismic field files (records) in SEG-2 format (e.g., *.dat, *.sg2, etc.).

If the files contain field geometry information [i.e., source/receiver (SR) setup] in the file header, then the program will detect it and ask you for review. Otherwise, the program will direct you to the SR setup process before the automatic process takes place.
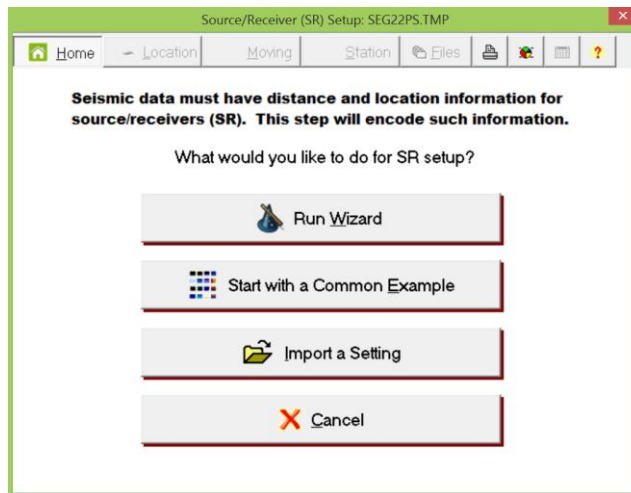
When clicked "Yes" to view the original SR setup, a chart will be displayed as shown below:

Review the configuration on the chart to see if it is the correct SR setup. Then, close it to have the following dialog displayed:
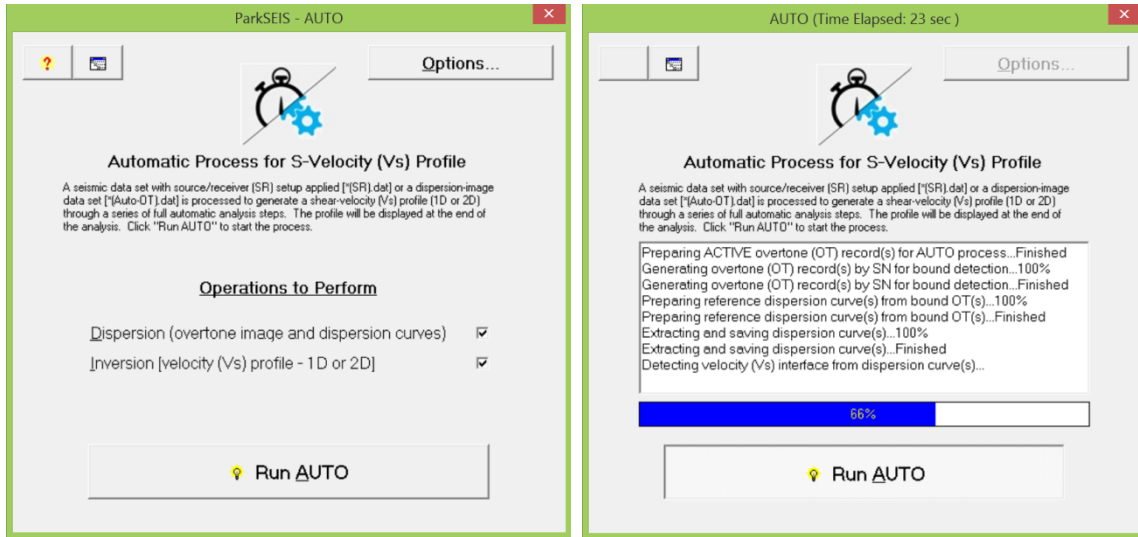

If the original SR setup is correct, then you can save the SEG-2 files as one file [*(SR).dat] and skip the subsequent SR setup process. Otherwise, select "Run source/receiver (SR) setup" to start the SR setup process before the automatic process takes place as shown below [refer to "Setup Source/Receiver (SR)" user guide for instructions]:

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
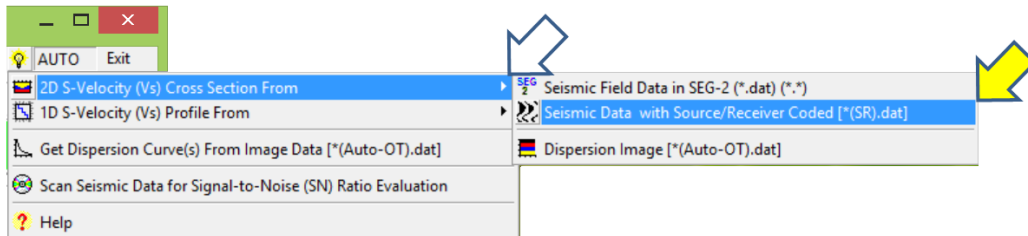

At the end of the process, the velocity (Vs) cross section will be displayed as shown below:

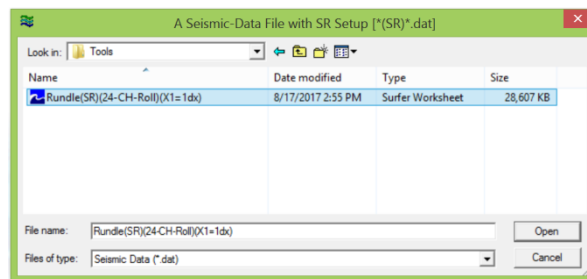## 2.2 From Seismic Data with Source/Receiver (SR) Setup
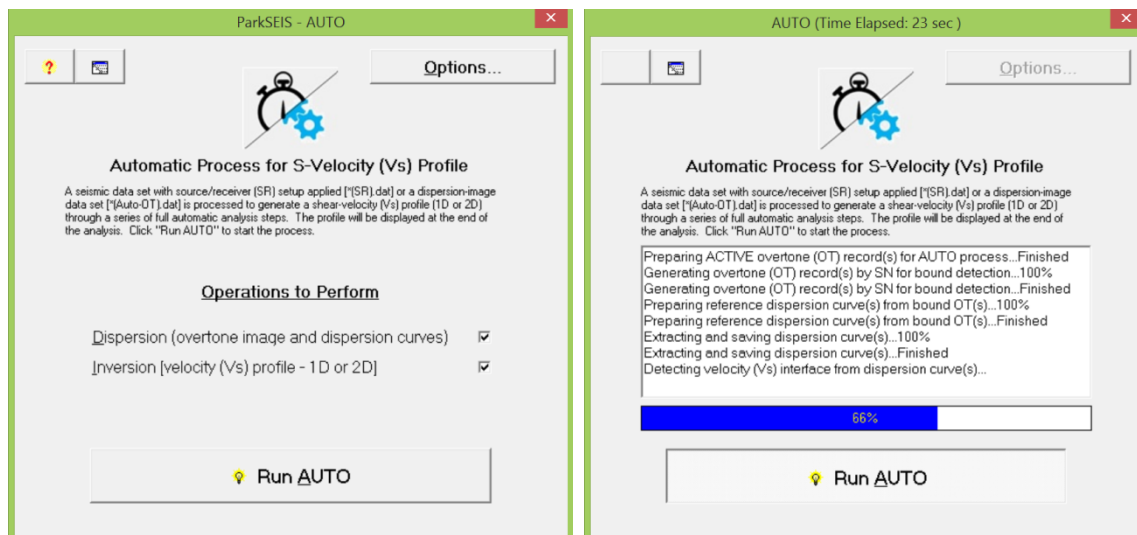
From the main menu, select items as shown below:

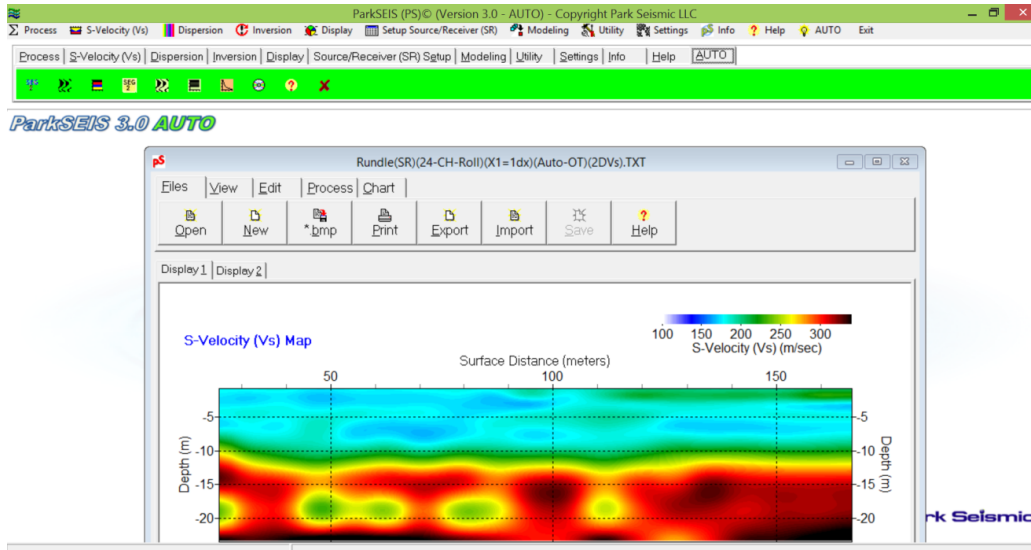Or, from the tool panel, select the button as shown below:

Select a seismic data file, previously prepared, that has source/receiver (SR) setup encoded [*(SR)*.dat].

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
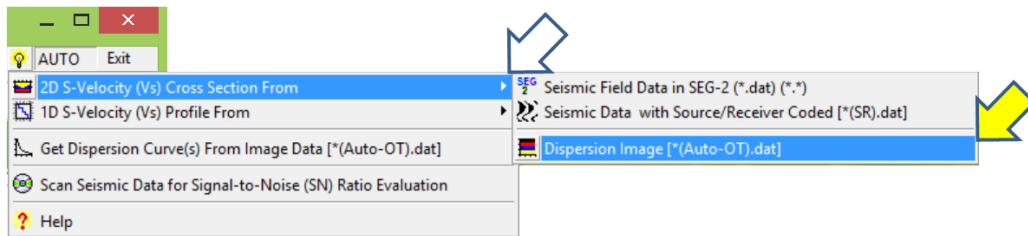
At the end of the process, the velocity (Vs) cross section will be displayed as shown below:


2.3 From Dispersion Image File

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

Select an overtone image data file [*(Auto-OT).dat] previously prepared that has multiple number of overtone records.

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):

At the end of the process, the velocity (Vs) cross section will be displayed as shown below:
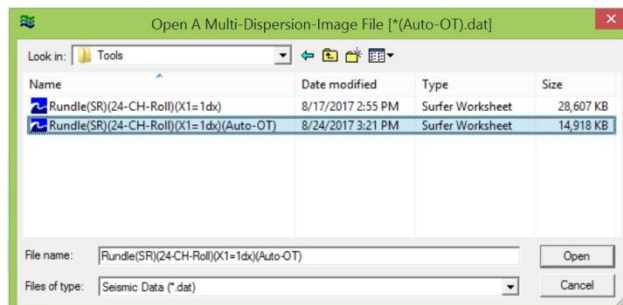
3. AUTO for 1D Velocity (Vs) Profile

This section describes the automatic process used to generate a 1D velocity (Vs) profile at the end [*(1DVs).LYR]. It can start from (3.1) original seismic field data in SEG-2 format that may or may not have the source/receiver (SR) setup encoded, (3.2) a seismic field data set previously prepared that has SR setup encoded [*(SR)*.dat], or (3.3) an overtone record data set previously prepared [*(Auto-OT).dat]. If the original SEG-2 seismic data set does not have a proper SR setup encoded, then you have to go through the source/receiver (SR) setup process first before the automatic process takes place.
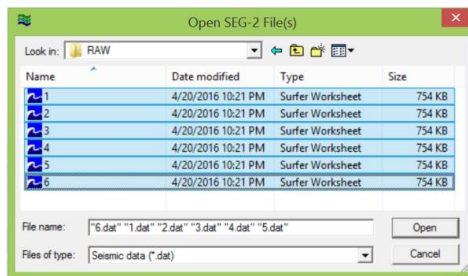
3.1 From Field Seismic Files in SEG-2 Format

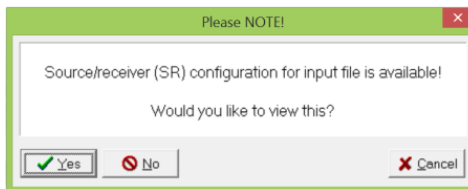From the main menu, select items as shown below:
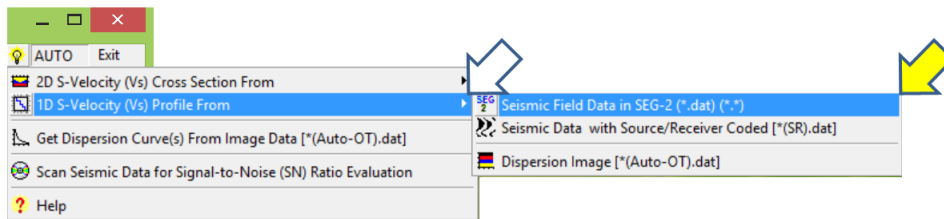
Or, from the tool panel, select the button as shown below:
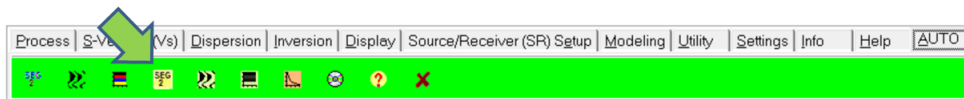
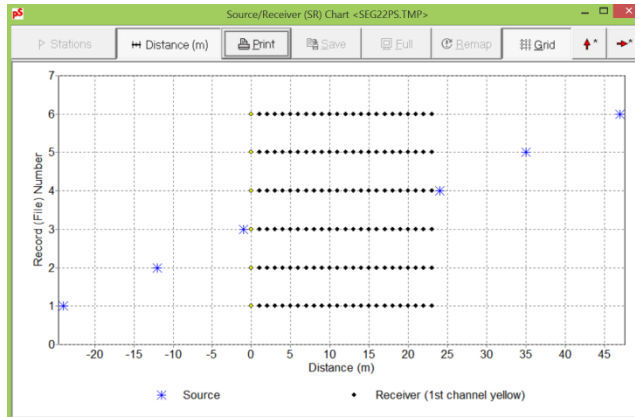Select one or multiple seismic field files (records) in SEG-2 format (e.g., *.dat, *.sg2, etc.).

If the files contain field geometry information [i.e., source/receiver (SR) setup] in the file header, then the program will detect it and ask you for review. Otherwise, the program will direct you to the SR setup process before the automatic process takes place.
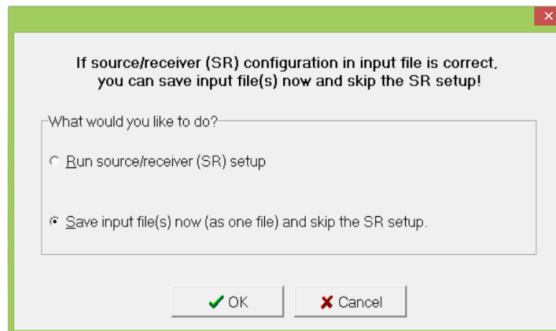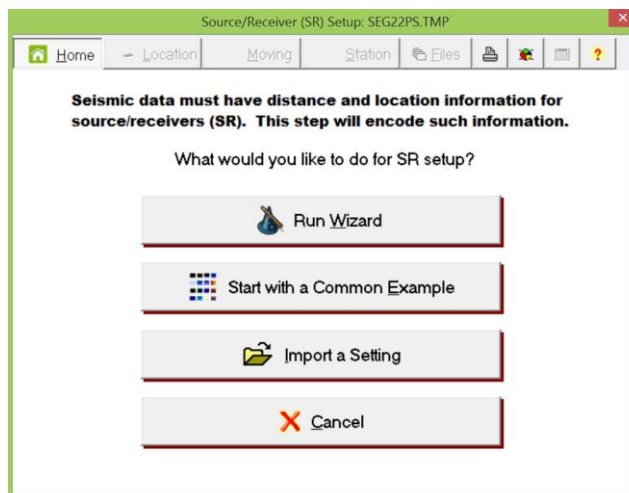
When clicked "Yes" to view the original SR setup, a chart will be displayed as shown below:

Review the configuration on the chart to see if it is the correct SR setup. Then, close it to have the following dialog displayed:
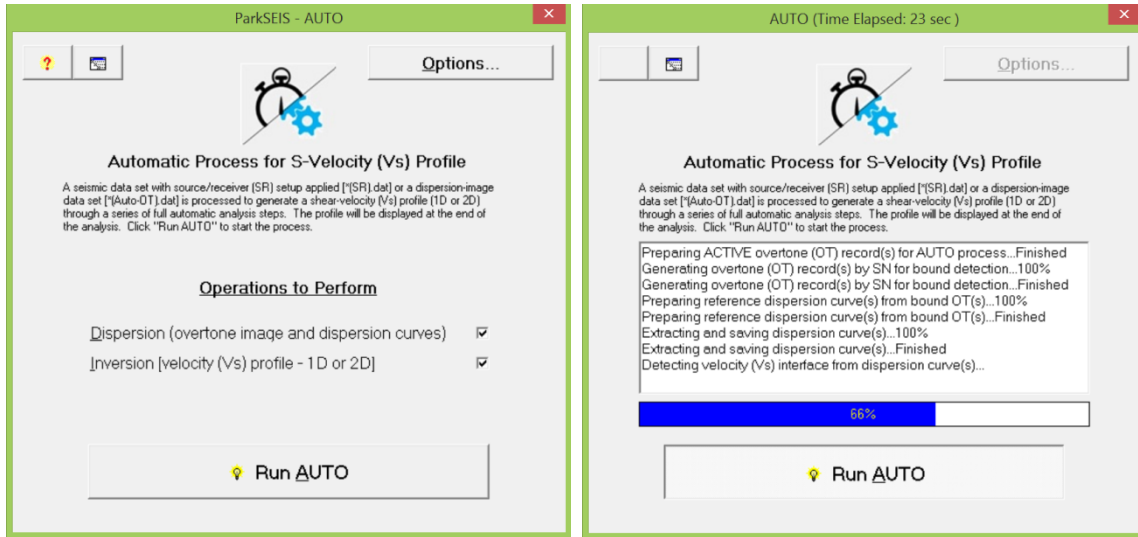

If the original SR setup is correct, then you can save the SEG-2 files as one file [*(SR).dat] and skip the subsequent SR setup process. Otherwise, select "Run source/receiver (SR) setup" to start the SR setup process before the automatic process takes place as shown below [refer to "Setup Source/Receiver (SR)" user guide for instructions]:
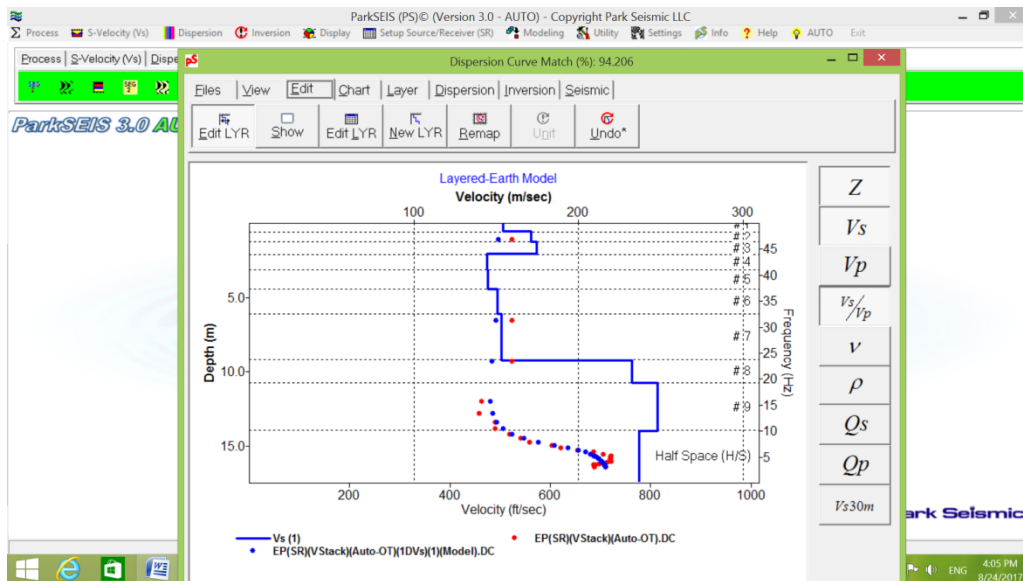

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Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
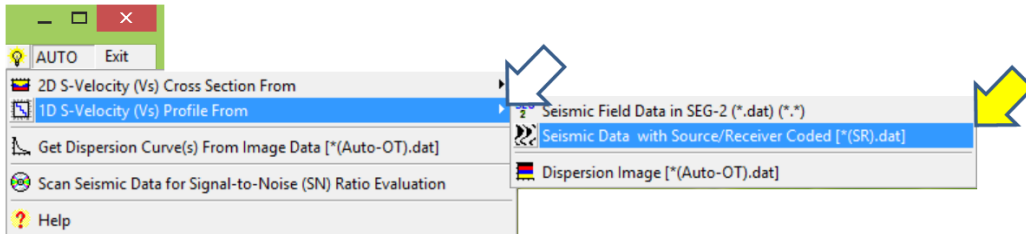

At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR} will be displayed as shown below:
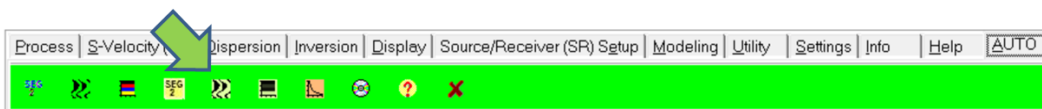
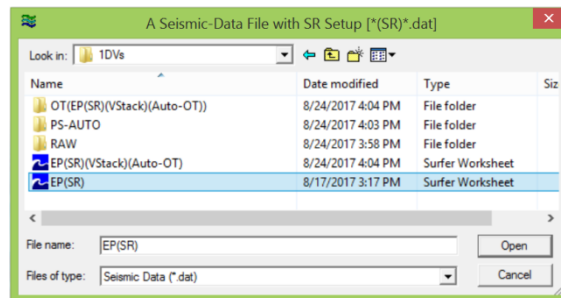## 3.2 From Seismic Data with Source/Receiver (SR) Setup

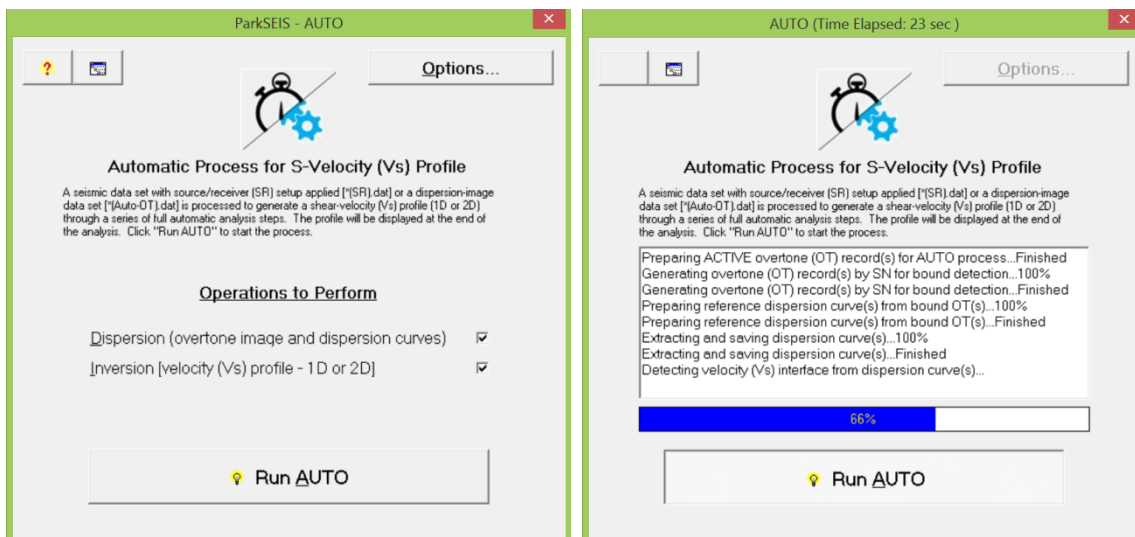From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

Select a seismic data file previously prepared that has source/receiver (SR) setup encoded [*(SR)*.dat].

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):

At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR] will be displayed as shown below:

3.3 From Dispersion Image File

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

Select an overtone image data file previously prepared [*(Auto-OT).dat].
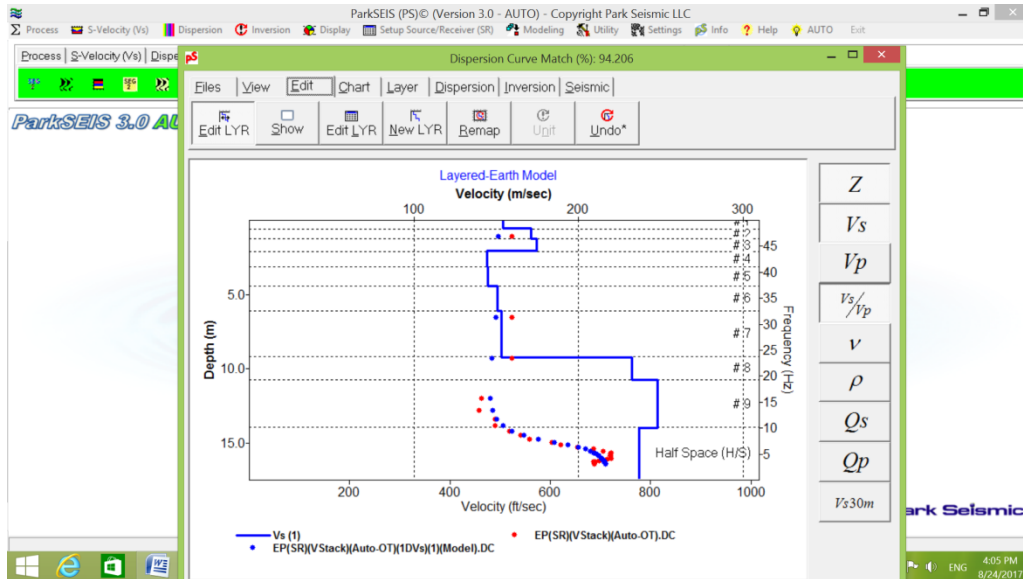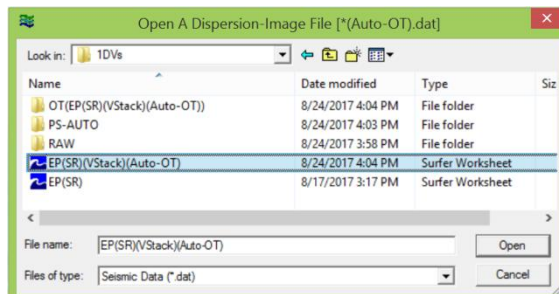
Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
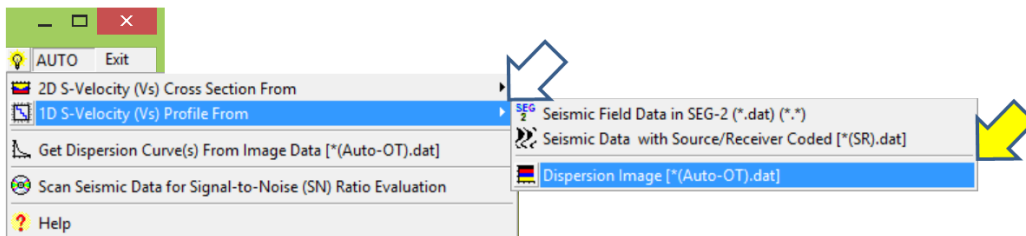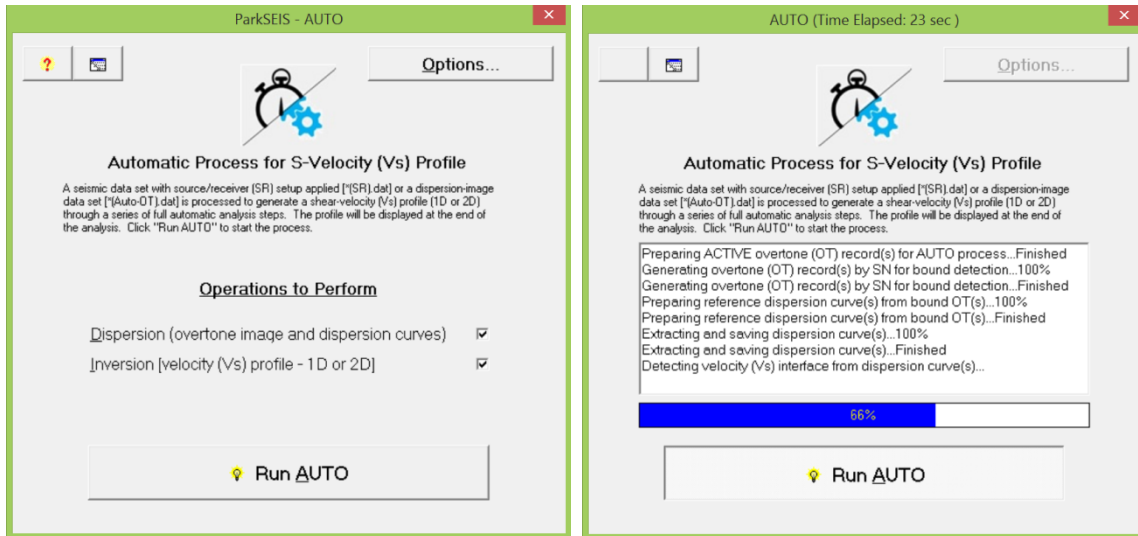

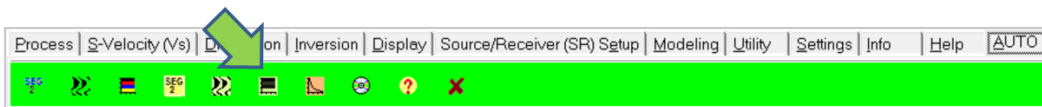At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR] will be displayed as shown below:
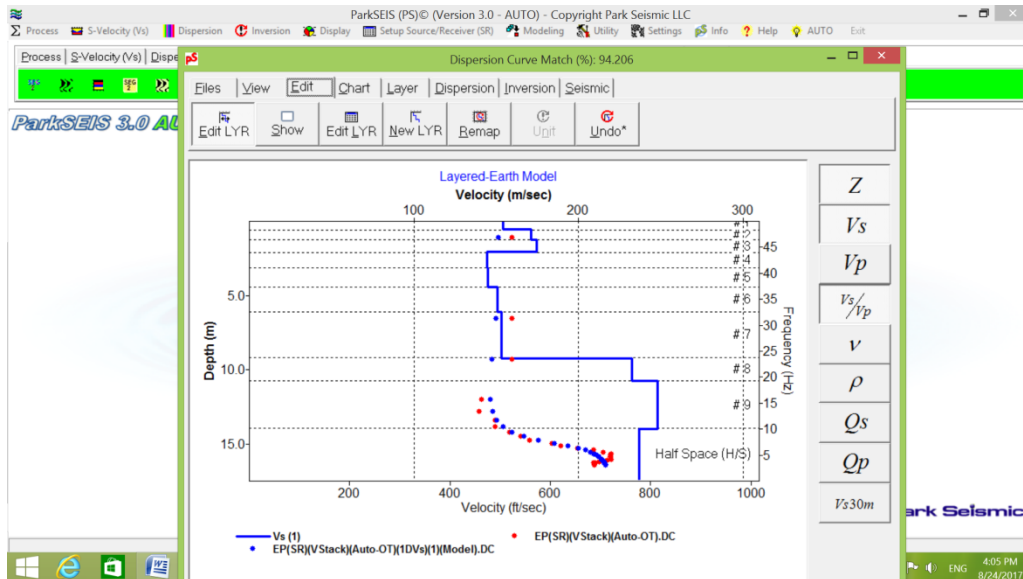
4. AUTO for Dispersion Curve Extraction

This section describes the automatic process used to generate dispersion curve(s) (*.DC) from an overtone data file [*(Auto-OT).dat]. Extracted dispersion curve(s) can be used for the inversion process to produce a velocity (Vs) profile (1D or 2D). This automatic process can take place in two different modes; (4.1) a batch mode that generates and saves all dispersion curve(s) without any user intervention, and (4.2) a pseudo-automatic mode that generates a dispersion curve for each overtone record being displayed in the chart. The second mode is available during the manual process to extract dispersion curve(s) from an overtone image file (the 2nd step of manual dispersion analysis).

4.1 Batch Process

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

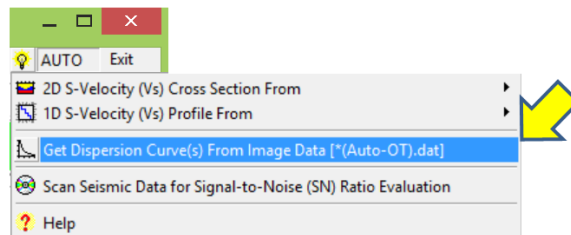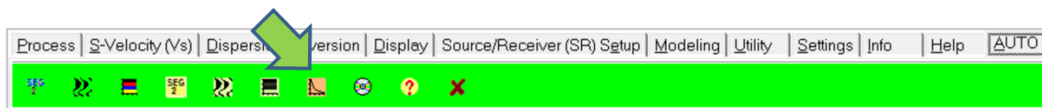Select an overtone image data file previously prepared [*(Auto-OT).dat].
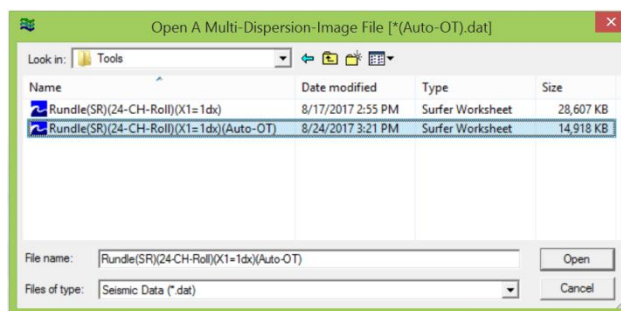
The program will detect the number of overtone records present in the input file and also the field geometry (SR setup) used during the acquisition of the original field files. Then, it will ask the user about the purpose of the process; i.e., 1D or 2D velocity (Vs) profiling. For 2D profiling, one dispersion curve will be extracted and saved from each of the overtone records included in the input file. On the other hand, for 1D profiling, only one dispersion curve will be extracted and saved by stacking all the overtone records included in the input file before the extraction takes place. The default is the most probable option the program detected.
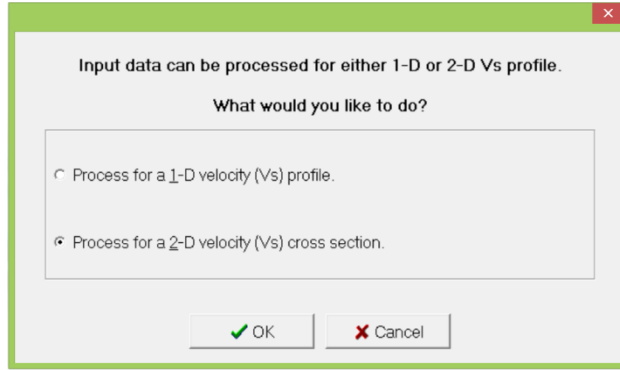
Click "Run AUTO" to start the AUTO process (left). It will proceed automatically with the processing status updated in the message panel as shown below (right):

At the end of the process, the file name of the saved dispersion curve(s) will be displayed as shown below:
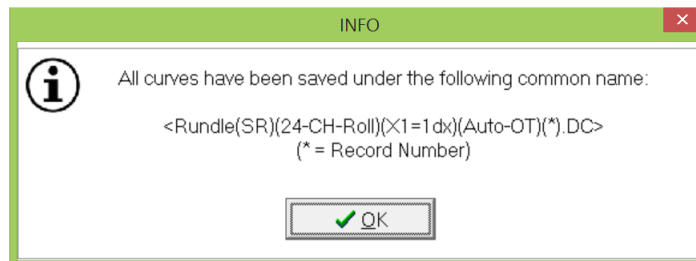
4.2 AUTO Process on Dispersion Image Chart

This section describes an AUTO process that can take place during the previous (manual) mode of dispersion-curve extraction (i.e., the 2nd step of dispersion analysis). Input to this process is an overtone image file [*(*OT).dat]. From the main menu, select items as shown below:
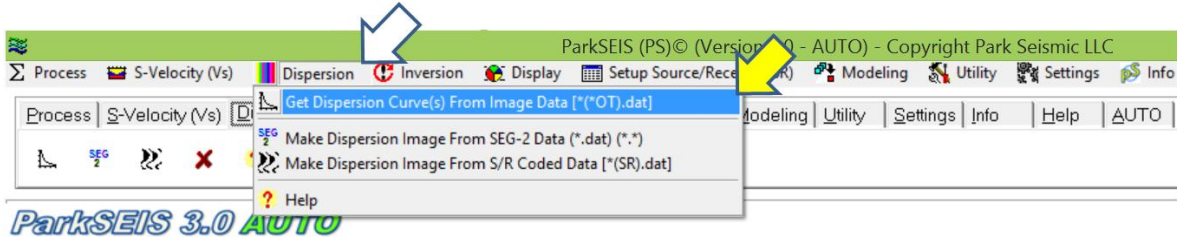

Or, from the tool panel, select the button as shown below:
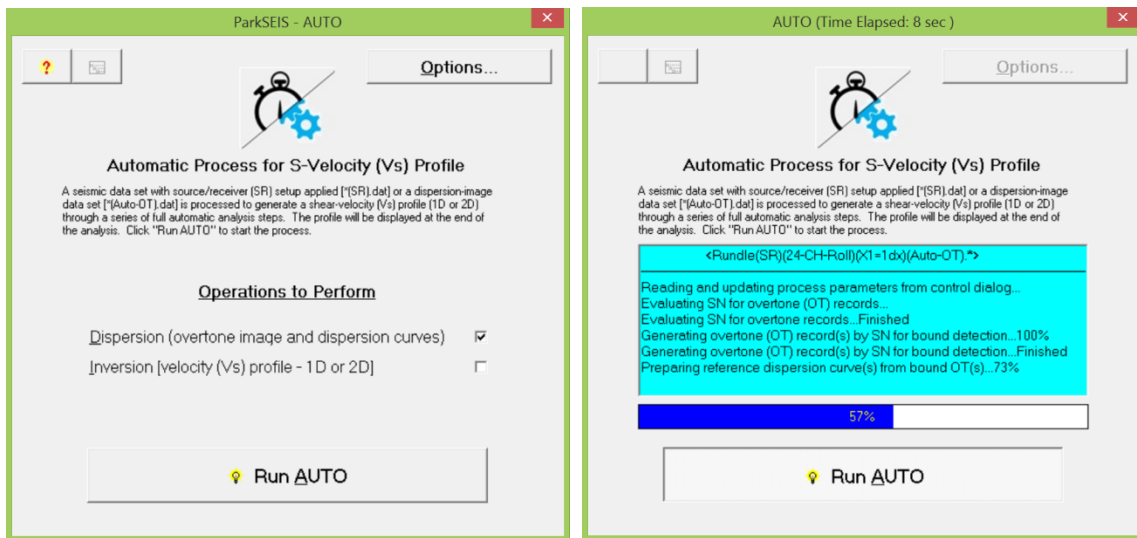

Select an overtone image file [*(*OT).dat]:
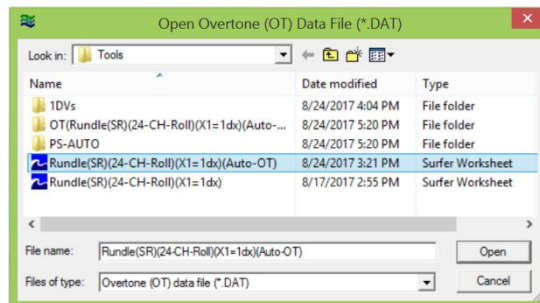
In the top tool panel of the displayed chart, click "AUTO" button:

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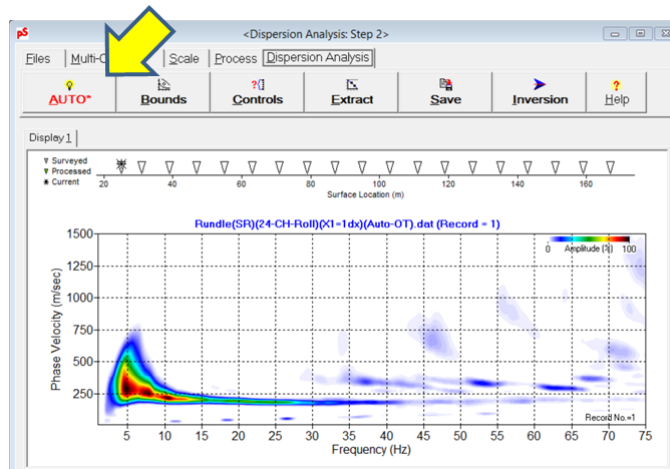
A control dialog will be displayed as shown below. Refer to "Section 6" for options available in this dialog. Click "OK" to proceed with all default parameters.
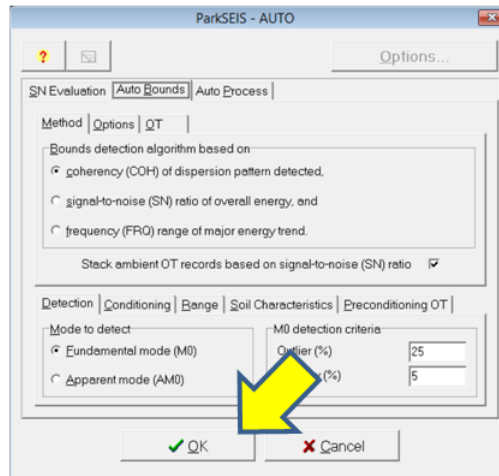
If the input file was generated from a previous AUTO run, then the program will detect it and try to use previous scanning results to facilitate the automatic curve extraction process. Click "Yes" to use them.
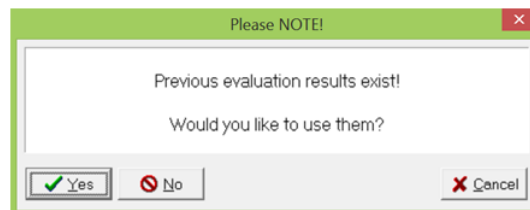
Otherwise, the program would want to proceed and run the "global" evaluation first before the automatic process takes place as shown below. It is always recommended to choose "Yes" (i.e., run the global evaluation) to enhance the effectiveness of the automatic process. If this global evaluation is not pre-performed, then the optimization of parameters for the automatic process will be based only on the local overtone record being processed. This can limit the effectiveness of the automatic process.
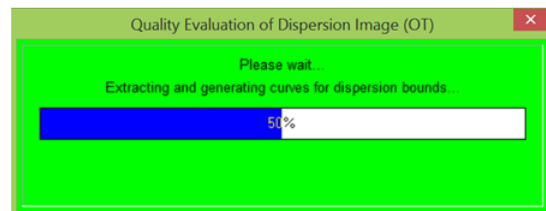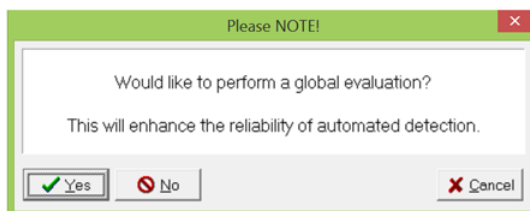
An automatically extracted dispersion curve will be displayed on top of the identified trend of the fundamental-mode dispersion as shown below. Examine the curve and then click "Save" button. The process will move to the next overtone record. Continue to click "Save" button after examination of each extracted curve until all overtone images are processed.
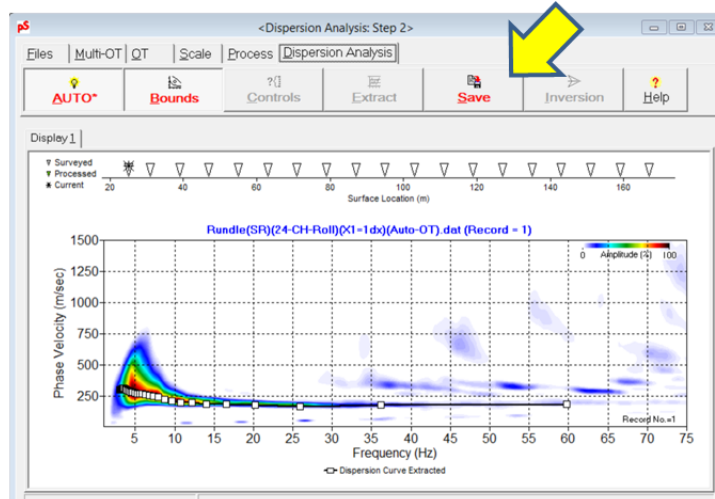
The normal curve-edit process (e.g., delete/add/move data points by using the mouse) can be applied to the extracted curve at any time before clicking the "Save" button as shown below:
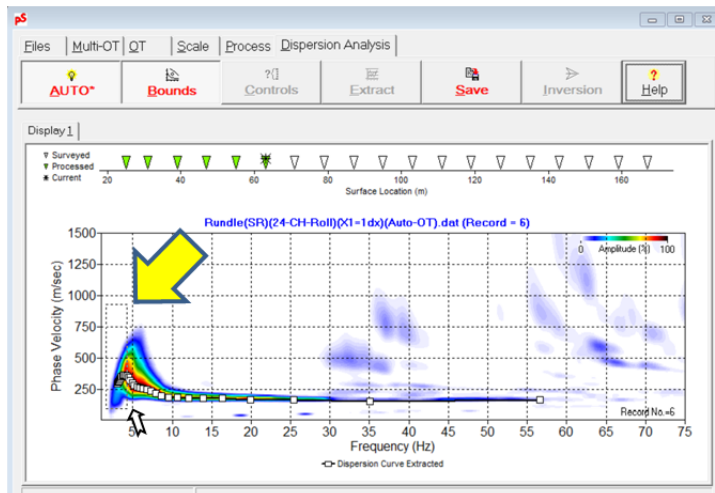
5. Scanning Seismic Data for SN Evaluation

This section describes an automatic process used to evaluate the signal-to-noise (SN) ratio of each record in a seismic data file [*(SR)*.dat]. Definition of SN ratio is based on the five attributes of an overtone record (processed from each seismic record) outlined in "Section 1. Overview"; **Pattern**, **Coherency**, **Definition**, **Amplitude**, and **Energy**. The evaluation results can be used to infer the overall "quality" of original seismic field records. In consequence, they can also be used to evaluate the relative confidence level of the final velocity (Vs) cross section by considering the record range that was responsible for specific lateral area in the cross section.

From the main menu, select items as shown below:
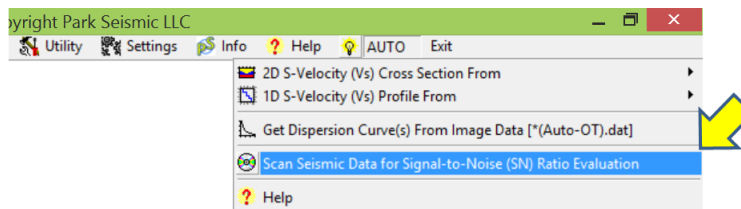
Or, from the tool panel, select the button as shown below:
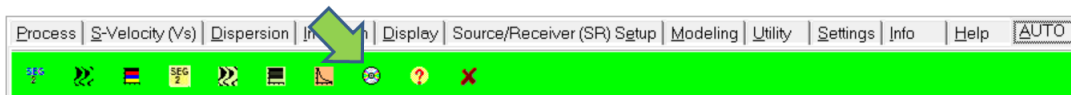
Select a seismic data file previously prepared that has source/receiver (SR) setup encoded [*(SR)*.dat].
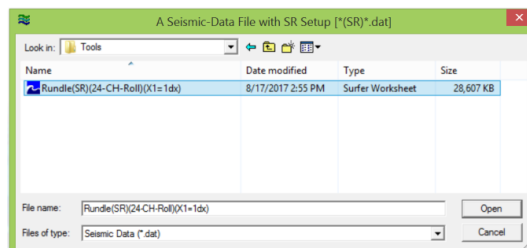
If the file was previously processed in AUTO mode, then the program will detect it and try to utilize the previous results.
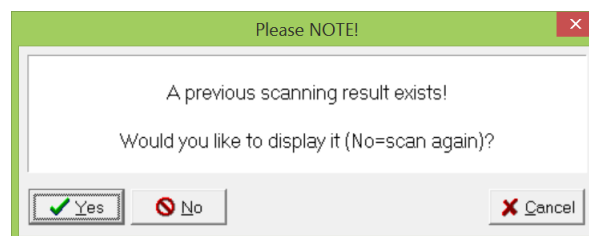
Otherwise, the program will run the scanning again without referring to the previous results as shown below:
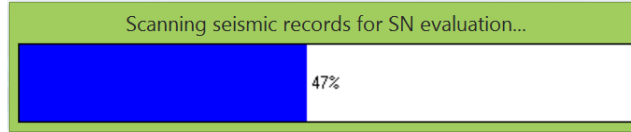
The final scanning results will be displayed in a chart as shown below:
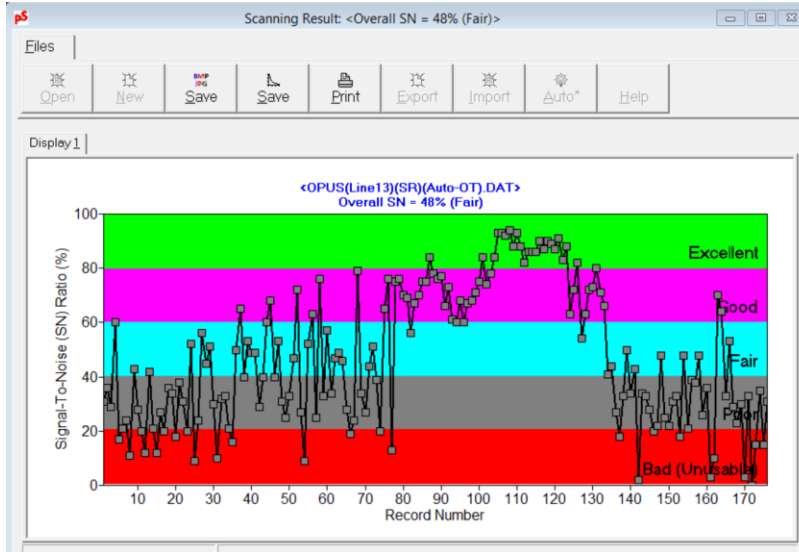
The scanning results shown above indicate that the velocity (Vs) results in 2D cross section corresponding to record numbers approximately in 80-130 are more reliable in comparison to other areas. The relationship between record number of seismic data and lateral distances in the cross section can be found by displaying the table of SR setup from a seismic data display (a button in "View" tab). Range of SN values and corresponding quality descriptions are presented in the table below:

Table 1: Description of SN vs. corresponding attributes.

SN (%)	Category	Quality Description
80-100	**Excellent**	Best quality for AUTO process. Highly reliable results are expected
60-80	**Good**	Good candidate for AUTO process. Reliable results are expected
40-60	**Fair**	Marginal quality for AUTO process. Results should be used with caution.
20-40	**Poor**	Lowest quality for AUTO process. Results should be used with caution.
0-20	**Bad (Unusable)**	Data should not be used for AUTO process.

6. "Options..." in AUTO

Options available during an AUTO process are explained here. By nature of an automated process, it is not expected that users will have to visit them often for any better optimization than the default settings the program already provides. **However, only those options that can influence the effectiveness of the overall process are briefly explained in this section to help understand what might have caused some features observed in the final result of velocity (Vs) profile.**

In the main page of the AUTO dialog, there are two main options of "Dispersion" and "Inversion" analyses as shown below. Both of them are always checked to generate the final velocity (Vs) profile unless the purpose is to generate only dispersion curves automatically (as explained in Section 4). To access all other options available, click the "Options..." button as shown below.
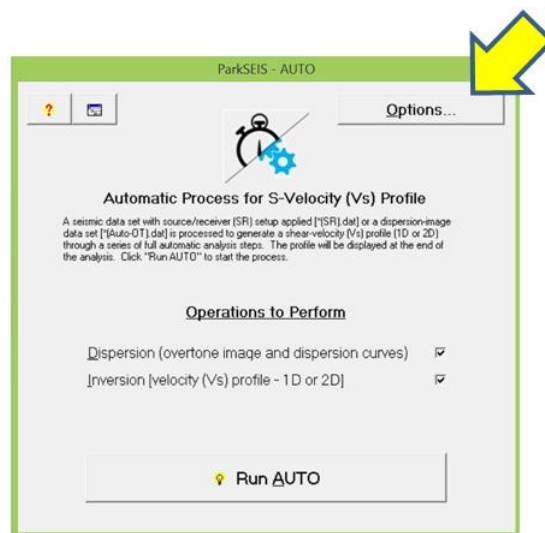
Auto Process Tab

Those options that can directly influence on the final velocity (Vs) profiles are included in this tab. The "**Save graphic (*.jpg) of extracted dispersion curve and image**" will save, if checked, the image (in JPG) of extracted dispersion curve superposed on the corresponding dispersion image during the automatic process of the curve extraction.

Spatial Resolution

This option, shown below, can influence on the (horizontal and vertical) resolution of the final 2D cross section. In theory, the highest resolution is most desirable. However, there are always adverse influences from the noise wavefields (i.e., everything rather than the fundamental-mode dispersion energy trend). Efforts to increase the detection ability of M0 trend in an overtone record will inevitably decrease the resolution at certain parts of dispersion image. Therefore, in practice, the automatic process is a tradeoff between a theoretical resolution and a practical effectiveness. Default values (75%) for both horizontal and vertical resolutions are the most optimum values empirically calibrated. The lower values will decrease the overall spatial resolution, but make the detection process more effective by suppressing adverse influences from the noise wavefields. On the other hand, the higher values may

increase the resolution if noise wavefields are insignificant. Therefore, for a seismic data set with complications (e.g., strong ambient noise and higher modes, severe lateral variation of subsurface conditions, poorly developed surface waves, etc.), the lower values (e.g., 50%) for both "**Horizontal**" and "**Vertical**" resolutions will make the automatic process more reliable. If the data set is in good quality, then the higher values (e.g., 100%) can generate a cross section with the highest spatial resolution the automatic process can ever achieve. The data quality can be assessed by the "Scanning" option described in Section 5. If the overall scanning result is "Good-Excellent" (≥ 60%), then the resolution values can be increased above the default values (e.g., 100%). If the result is "Poor-Bad" (≤ 40%), then it is recommended to lower the values (e.g., 50%).

Dispersion and Inversion

Options to change parameters for dispersion ("**Dispersion Curve**") and inversion ("**Inversion**") analyses are shown below. They are the same options available when performing each analysis in a manual mode.
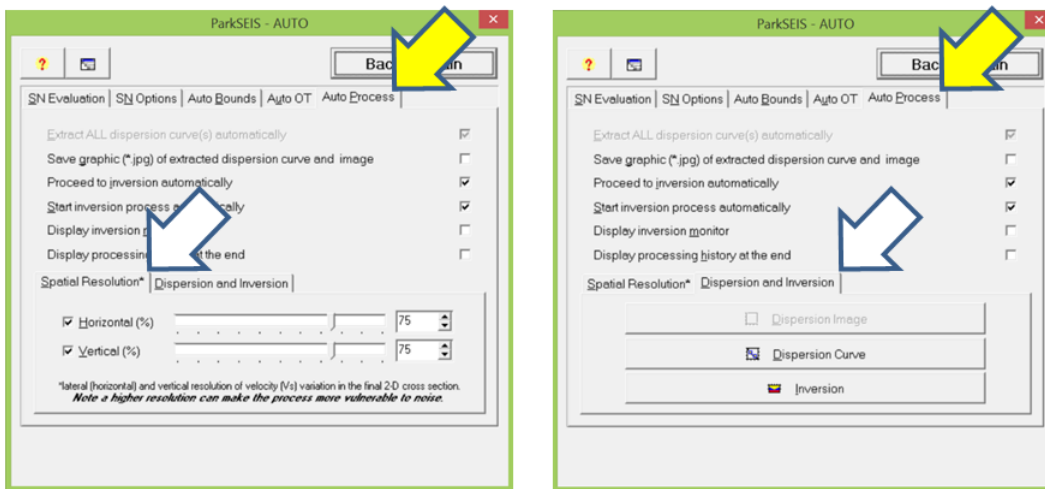

Auto OT Tab

Parameters that can influence some features of the overtone records [*(Auto-OT).dat] are available on this tab. For example, in the "**Frequency range (Hz)**" box, you can change the start ("**MIN**") and ending ("**MAX**") frequencies, as well as the interval ["**Interval (after resampling)**"], of the overtone record.   All options available in this tab are directly related to the suppression of computational artifacts inevitably generated from a 2D wavefield transformation.

Wavelength and Smoothing

The shortest ("**MIN**") and the longest ("**MAX**) wavelengths in the overtone record are specified. Energy outside this bound will be muted (i.e., zeroed). Smoothing of an overtone image is applied by the parameters specified in the "**OT Smoothing (# of samples)**" box as shown below.   A higher number will apply a wilder smoothing along the corresponding axis (i.e., "**Frequency axis**" or "**Phase velocity axis**").

Tapering and Filtering

Tapering at the beginning and ending parts of the frequency axis of an overtone record is specified in the "**Tapering**" box; 0=no tapering, 1=weak tapering, 2=mild tapering, and 3=strong tapering will be applied. The exact amount of tapering for each option (0-3) is determined with reference to the spectral characteristics of the original seismic record. The "**Noise filter**" specifies the extent (%) of filtering background noise wavefields in an overtone record.
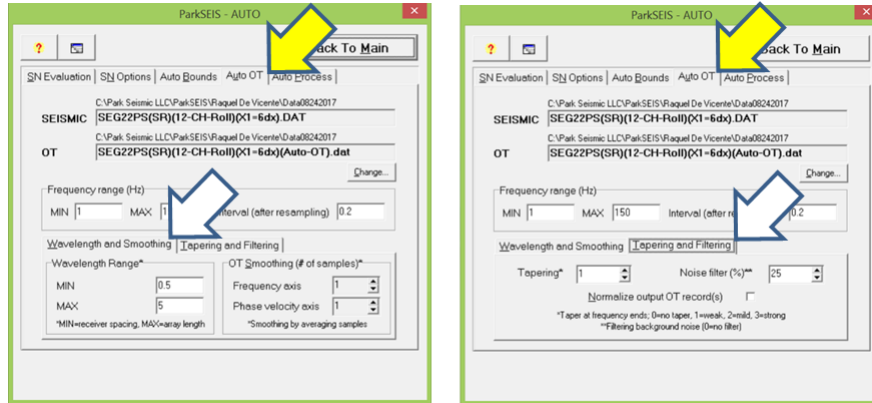

Auto Bounds Tab

Parameters that can influence some features of the special overtone data set [*(Bound-OT).dat] can be changed from this tab. This overtone data set is generated by recognizing patterns in the original overtone record data set [*(Auto-OT).dat]. It is used to generate a special type of dispersion curve [*(BoundDC).DC] for each overtone record that is in turn used to set the (lower and upper) bounds for the subsequent process to extract a dispersion curve from the original overtone record [*(Auto-OT).dat].

The "**Method**" tab shows different options that can be used to extract the bound dispersion curve [*(BoundDC).DC]. Default option ["**coherency (COH) of dispersion pattern detected**"] is always recommended. "**Options**" and "**OT**" tabs contain parameters that are important only from coding perspectives. The "**Detection**" tab at the bottom of the page shows the mode of detection to be chosen ("**Mode to detect**"). The "**Fundamental mode (M0)**" will focus only to the fundamental mode during the detection process, whereas the "**Apparent mode (AM0)**" will focus on the pattern created by the strong energy trend without evaluation of the possible mode(s). All other options are important only from the coding perspectives.
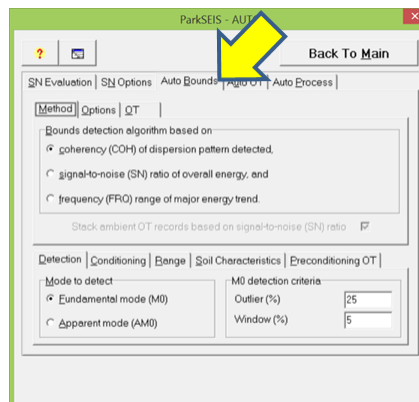
SN Options Tab

Parameters related to a specific method of signal-to-noise (SN) ratio evaluation are gathered on this page. All of them are important only from the coding perspectives.
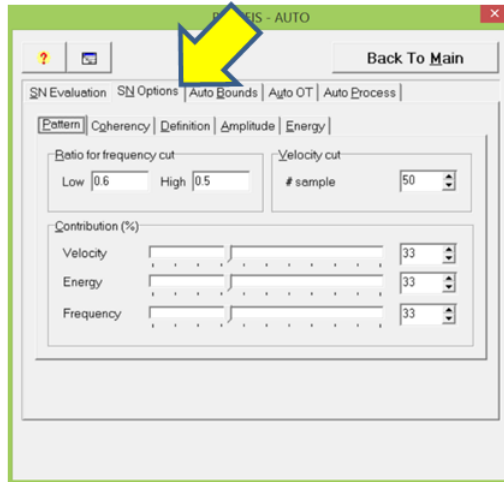
SN Evaluation Tab

Parameters related to the SN ratio evaluation (by using a specific method) are gathered on this page. All of them are important only from the coding perspectives.