# Dispersion Image Generation


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# 1. Overview

This module generates dispersion image data [*(*OT).dat] from raw field records of either SEG-2 format (e.g., *.dat) or PS format that has source/receiver (SR) configuration encoded [*(SR).dat]. The image data set will also have the same PS format adopted for all types of seismic data saved by the PS program. The specific type of data (e.g., seismic or dispersion image) will be detected by the software based on specific codes embedded in the data headers. The image data set is generated by two-dimensional (2-D) wavefield transformation methods applied to the field data that must have correct information about source-receiver distance for each channel's data (trace). The program will detect this at the beginning and will not proceed if proper information is not detected.

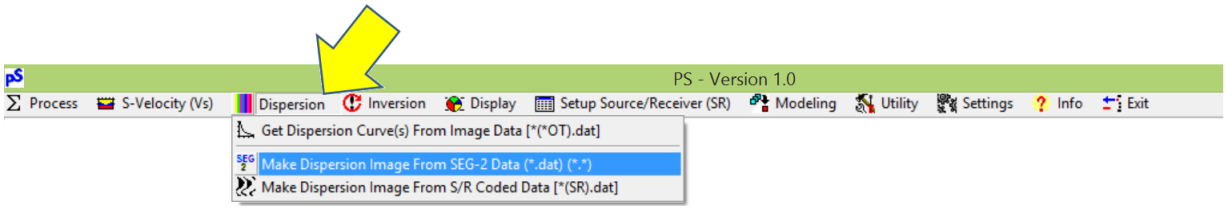
The wavefield transformation method of Park et al. (1998) is the fundamental algorithm used. Significant improvements have been made since this algorithm was first published. These improvements allow this method to produce more accurate images even with relative low signal-to-noise ratio (SN) in the input data. Improvements by Park (2011) provided an option that can selectively apply the transformation to relevant offset ranges for different wavelengths so that the high-frequency portion of the dispersion can be more clearly imaged. In addition, many other factors have been discovered through extensive study that can contribute positively to a "better-quality" dispersion image if properly controlled. These additional factors have been included as controllable parameters at the appropriate places in the dialog.

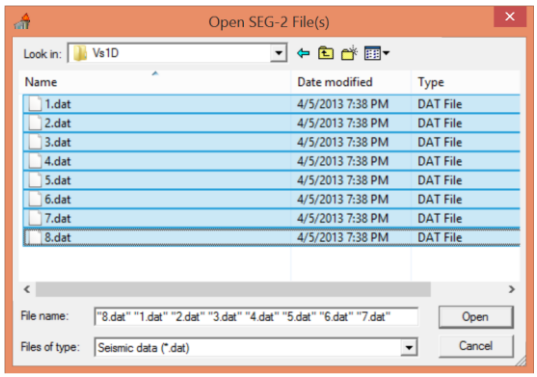
The imaging method for passive data originally started with the method by Park et al. (2004) that later turned out to be quite analogous to the spectral auto-correlation (SPAC) method by Aki (1957), only expressed in a different mathematical formulation with a few extra variables. This method then evolved to Park and Miller (2008) to handle traffic-generated passive surface waves more effectively. This further evolved into the method by Park (2008) that utilized the conventional active scheme by accurately detecting the incoming angle (azimuth) of those passive surface waves of major contribution. The most recent method by Park (2010) further elaborated this approach by accounting for possible changes in azimuth during the long recording time (i.e., dynamic detection of azimuth). Although this dynamic method is the most recent method that can account for many complications, it is by no means absolutely superior to its predecessors without any exceptions. In fact, depending on the specific situation, one of the old methods might provide more accurate results by addressing some particular characteristics better than any other method could. Therefore, all these methods are included in the dialog as selectable options. The program, however, will choose as the default what it determines to be the optimal method by examining a few key features of the input data, such as type of receiver array used (e.g., 1-D or 2-D), recording time, etc.

The imaging method for data sets from the active/passive combined survey will be an exact combination of both active and passive schemes. The early portion of the input data (e.g., ≤ 2 seconds) will be treated as active data, while the remaining portion will be treated as passive data.

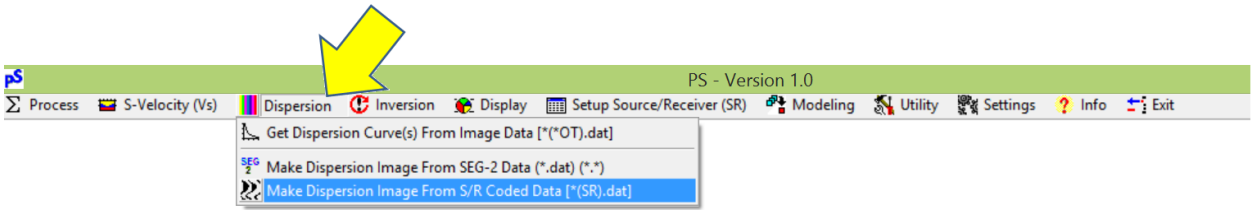
# 2. Importing Input Data

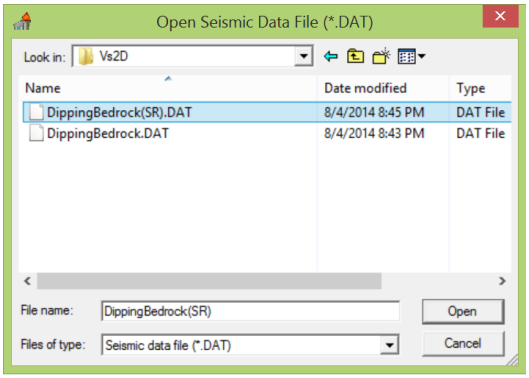
To import field files (records) of SEG-2 format, go to "Dispersion" → "Make Dispersion Image From SEG-2 Data" in main menu. Then, select all the files at the same time. If input records require a new source/receiver (SR) configuration setup, then the program will launch the SR setup first. See PS User Guide "Source/Receiver (SR) Setup" for more information about encoding the SR setup.




To import a data set of field records already in PS format with a proper source/receiver (SR) configuration encoded, go to "Dispersion" → "Make Dispersion Image From S/R Coded Data" and then select one file.

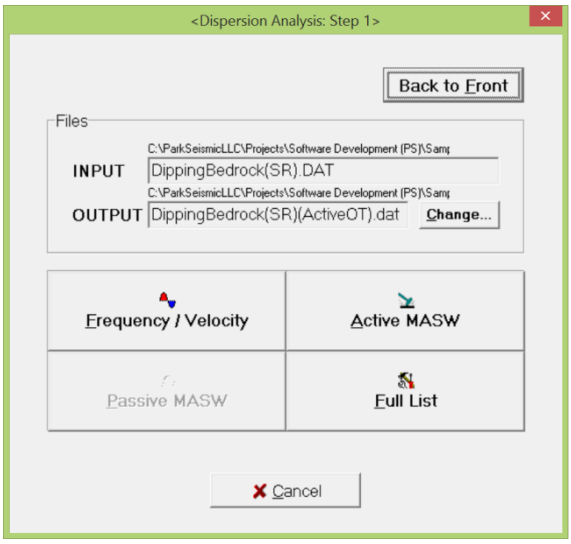


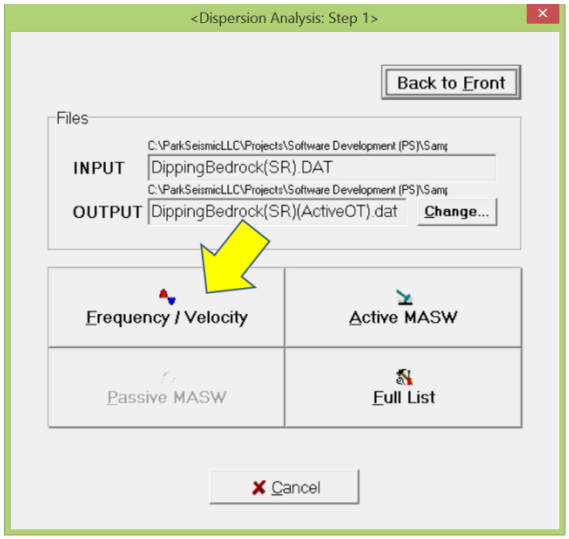
# 3. Main Dialog

After importing input data, the following main dialog will appear. Click "Run Dispersion Image" to launch the process with default processing parameters (which are automatically chosen by the program after examination of key characteristics of input data such as spectral contents, phase velocity ranges detected, receiver spacing, source offset, number of channels, etc.). Click the "Options..." button to have access to all such parameters.

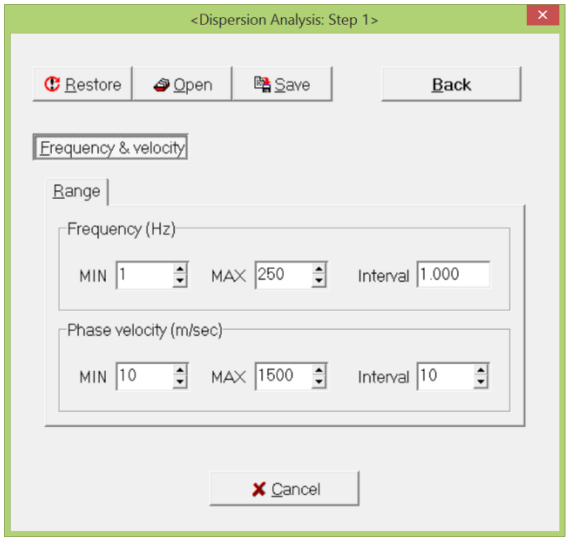

Control parameters are grouped into four (4) categories: "Frequency/Velocity", "Active MASW", "Passive MASW", and "Full List."



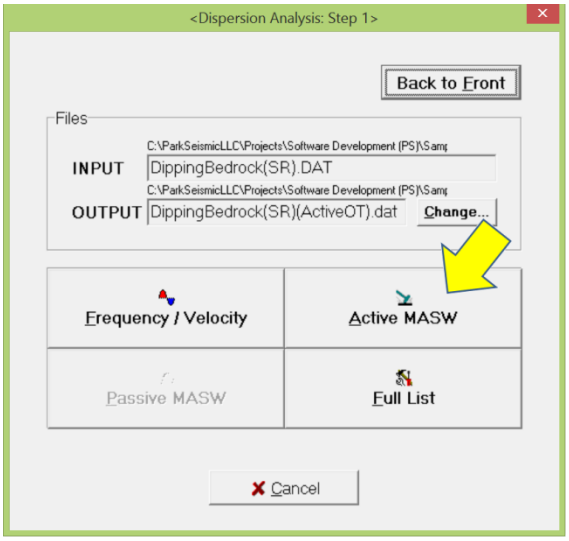
# 4. Frequency/Velocity




Ranges in frequency (*f*) and phase velocity (*Vphs*) are specified here that are used during the 2-D (f-Vphs) wavefield transformation. MIN and MAX values of frequency (*f*) and phase velocity (*Vphs*) will determine the size of the dispersion image by setting corresponding values for horizontal (*f*) and vertical (*Vphs*) axes of the image space. The "Restore" button will restore values for all the parameters last used. Clicking "Open" will allow import of a set of previously saved parameters or clicking "Save" will save a current set of parameters as a file (*.VA_).

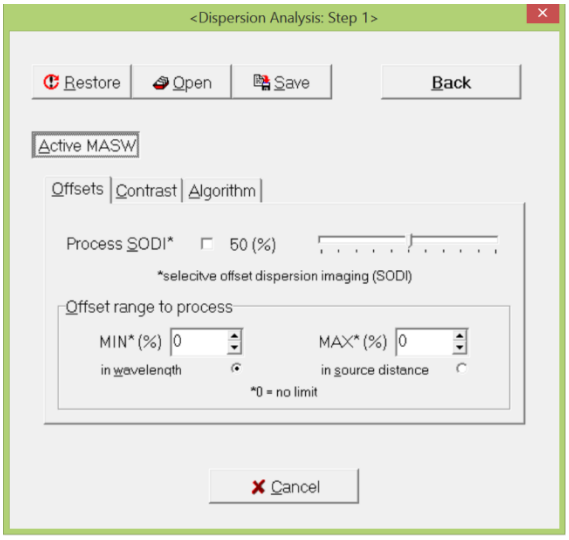


# 5. Active MASW



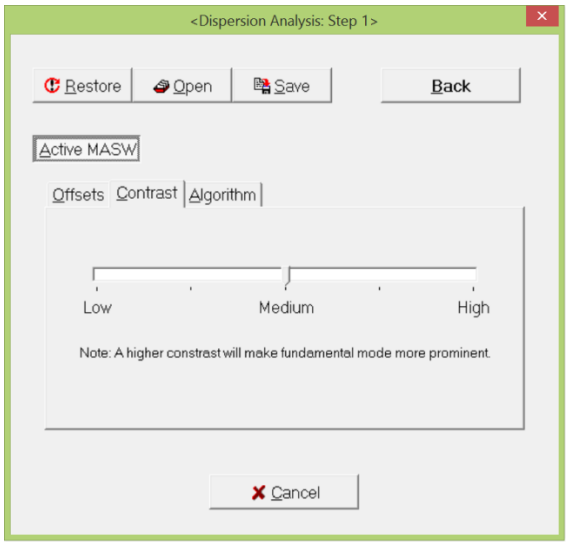

## 5.1 Offsets

If the "Process SODI" box is checked, offset-selective (instead of "full-offset") processing will be applied in which the processing offset range changes with wavelengths (see Park, 2011). The degree (%) that can be adjusted by the sliding bar on the right controls the extent of the selectiveness; the greater the percent, the more aggressive. Minimum and maximum (MIN and MAX) offset in the lower box will set the offset range manually in either percent of wavelength (%) or source distance (that will be common for all wavelengths).



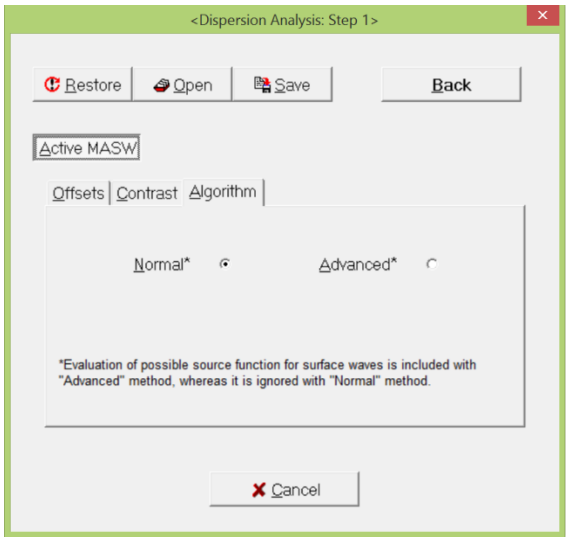
## 5.2 Contrast

This controls the relative "brightness" in a dispersion image that can make patterns of certain weak energy more ("Lower" contrast) or less ("Higher" contrast) pronounced. This is sometimes useful to subdue higher modes patterns and emphasize patterns of the fundamental mode.

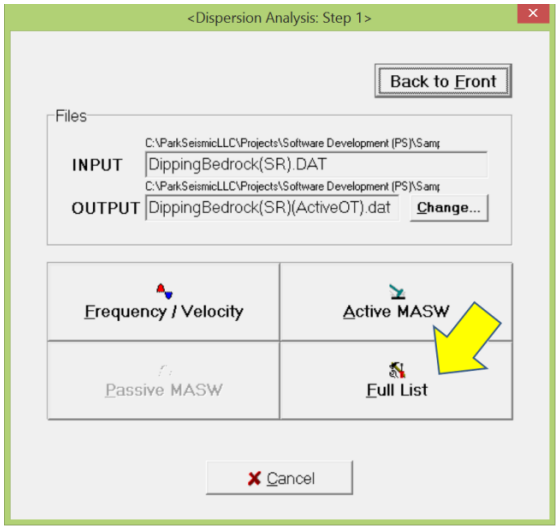



## 5.3 Algorithm

The "Normal" algorithm will use only the relative arrival time (i.e. phase) difference between different channels during the image construction, whereas the "Advanced" option will attempt to account for the absolute arrival times (phases) of surface waves for different frequencies. The former algorithm will suppress computational artifacts (e.g., side lobes), whereas the latter will increase the resolution of dispersion patterns.

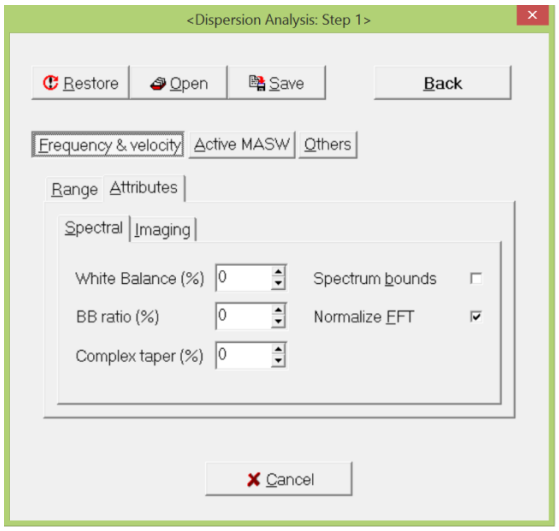


# 6. Full List

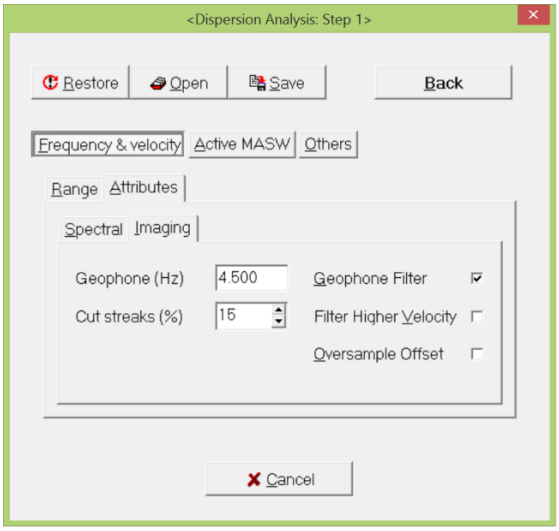



## 6.1 Attributes

The "White Balance (%)" will add, if a non-zero value is chosen, an infinitesimal amount of random noise during the wavefield transformation (FFT) to suppress most of computational artifacts (e.g., linear streaks). However, it will mask useful dispersion patterns of weak energy (if they exist) especially at the lowest frequency end of the image. If the box is checked, the "Spectrum bounds" will set the processing frequency range only within the detected range of significant energy (e.g., ~90%). The "BB ratio (%)" controls the width of broad band (BB) used during the wavefield calculation for each wavelength. A non-zero value will lead to a summation of wavefields at ambient frequencies. If the box is checked, the "Normalize FFT" applies the normalization of individual frequency component after the Fast Fourier Transformation (FFT) has been applied to the input seismic data. If a non-zero value is chosen, the "Complex taper (%)" applies tapering at both spatial edges (i.e., sides) of the input seismic record after FFT. This can sometimes lead to the reduction of computational artifacts in the image depending on the energy distribution in the input seismic data.

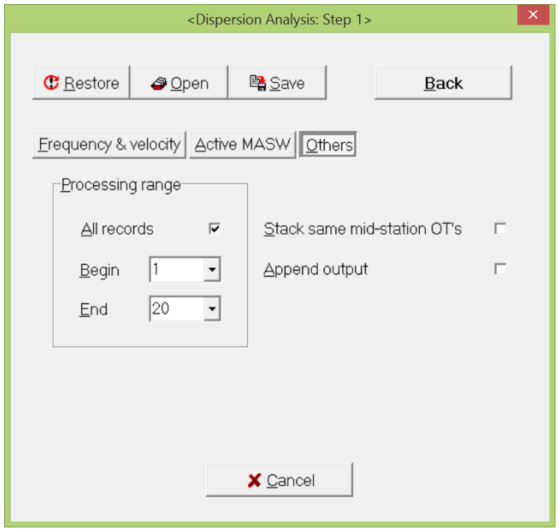


If the box is checked, the "Geophone Filter" mutes all amplitudes in the image space that exist at frequencies lower than the value specified in the "Geophone (Hz)" box on the left. If a non-zero value is chosen, the "Cut streaks (%)" will apply the muting for the zone influenced by the spatial aliasing effects. A greater value will apply more aggressive muting. If the box is checked, the "Filter Higher Velocity" will apply frequency-wave number (f-k) filtering to the input seismic data to remove all linear events faster than the highest phase velocity specified in the "Frequency/Velocity" tab. If checked, the "Oversample Offset" will apply the spatial interpolation to the input seismic data to help reduce the harmful influence of the spatial aliasing effects. This can also make the high phase-velocity dispersion patterns smear depending on the highest phase velocity specified in the tab.



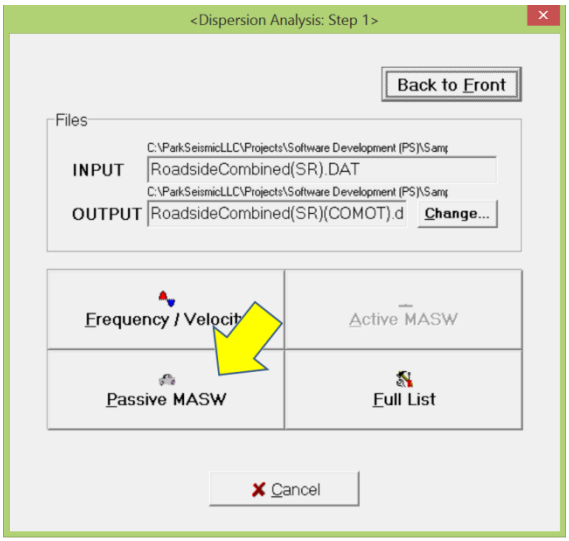

## 6.2 Others

The "Processing range" specifies the input records that are used to generate dispersion images. The "Stack same mid-station OT's" will stack (if checked) all dispersion images of the same surface location (mid-station) and then save the stacked image as output. If checked, the "Append output" will add generated dispersion image data at the end of the existing file of the same type.



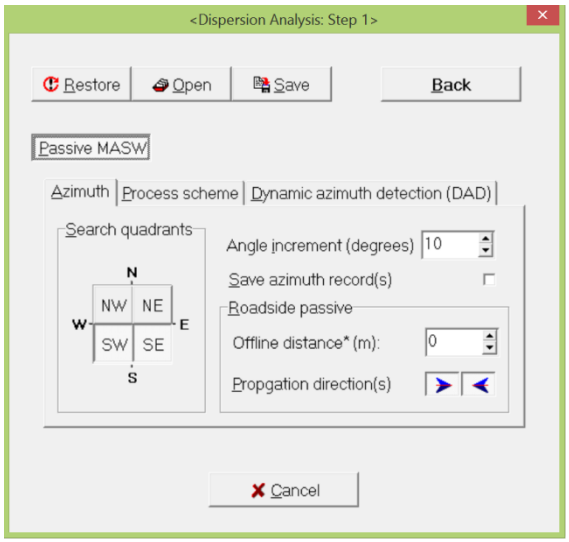
# 7. Passive MASW

The "Passive MASW" button is enabled only when input data is from either a passive or an (active/passive) combined survey.




## 7.1 Azimuth

The "Search quadrants" indicates those quadrants of azimuth within which incoming surface waves will be searched. When a 1-D receiver array (RA) was used during the survey, then the survey line's orientation is assumed to be in the E-W direction and only two consecutive quadrants (either SW - SE or NW - NE) are selected by the program. For 2-D RA, all four (4) quadrants are selected. The "Angle increment (degrees)" sets the interval of azimuth in degrees during the searching process. The "Save azimuth record(s)" will, if checked, save separate record(s) of detected azimuth-energy distribution for each input seismic record that will show relative distribution of surface wave energy for different azimuths and also for different frequencies. If a non-zero value is chosen, the "Offline distance* (m):" value will account for the offline effect of surface waves by considering a cylindrical (instead of planar) propagation of surface waves; but only inline (plane wave) propagation will be considered if a zero value is entered. See Park and Miller (2008) for more details about the algorithm. For inline propagation, both directions (forward and reverse) are considered by default as possible incoming directions of surface waves.

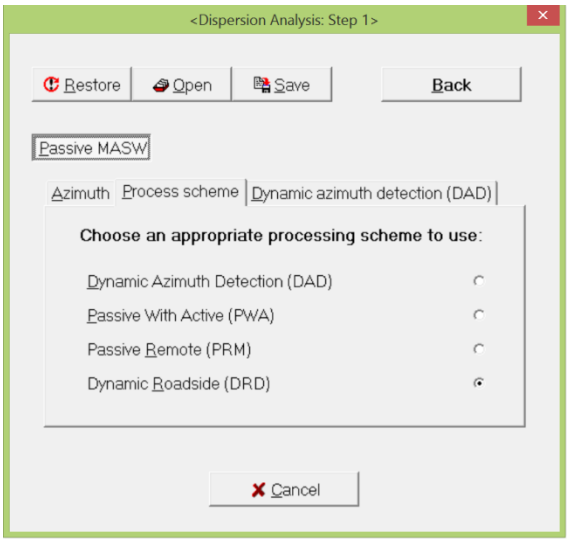



## 7.2 Process Scheme

Each scheme is briefly described in the Overview of this guide, and fully described in the following publications:

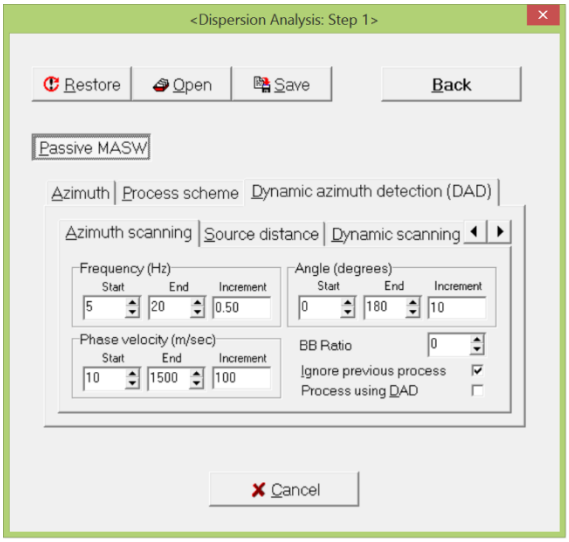
- DAD – Park (2010)
- PWA – Park (2008)
- PRM – Park et al. (2004)
- DRD – Park (2010); Park and Miller (2008)

If a 1-D receiver array (RA) was used, the DRD will be the default option. The DAD will be the default if a 2-D RA was used.

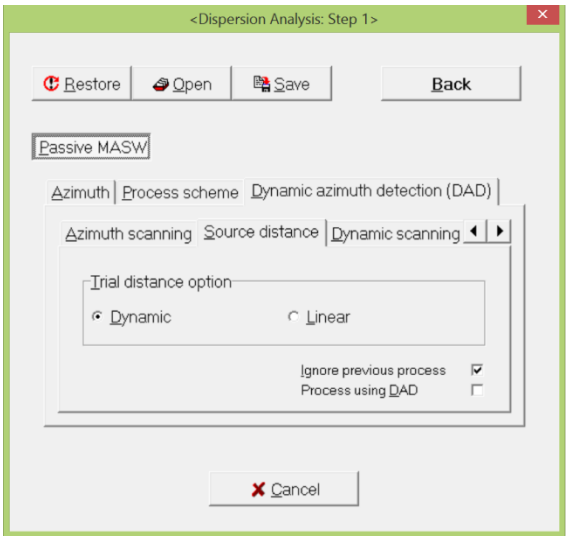


## 7.3 Dynamic Azimuth Detection (DAD)

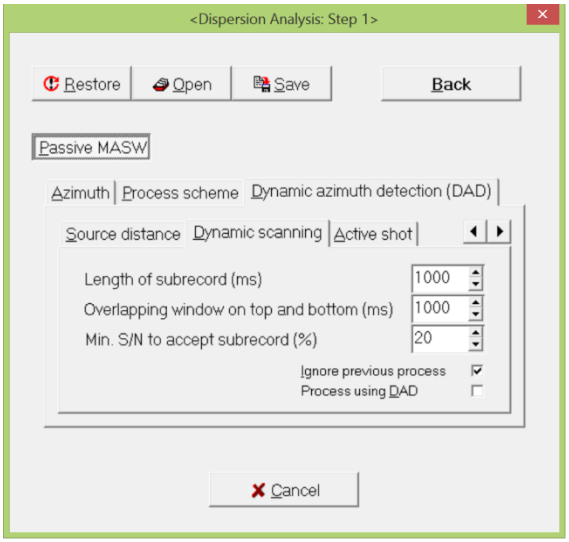
This section contains all the parameters related to the DAD scheme by Park (2010). The "Azimuth scanning" tab holds parameters for start, end, and interval of the three variables used during the detection (scanning) of surface waves—frequency, phase velocity, and azimuth. The "BB Ratio" will apply, if a non-zero value is chosen, the broad band (BB) summation of ambient frequencies during the scanning. If checked, the "Ignore previous process" will ignore all previous intermediate results that are automatically saved during the entire DAD process (e.g., azimuth-energy distribution records, source-distance distribution records, etc.). Therefore, each DAD process will be a "fresh" start if this option is checked. The "Process using DAD" will apply, if checked, the actual DAD algorithm and, otherwise, all parameters in DAD tab will not be used. This option will be checked by default only when a 2-D receiver array (RA) was used during the survey. If a 1-D RA was used, then the dynamic inline detection (instead of dynamic azimuth detection) will be applied to detect the orientation of incoming surface waves (i.e., forward or reverse).



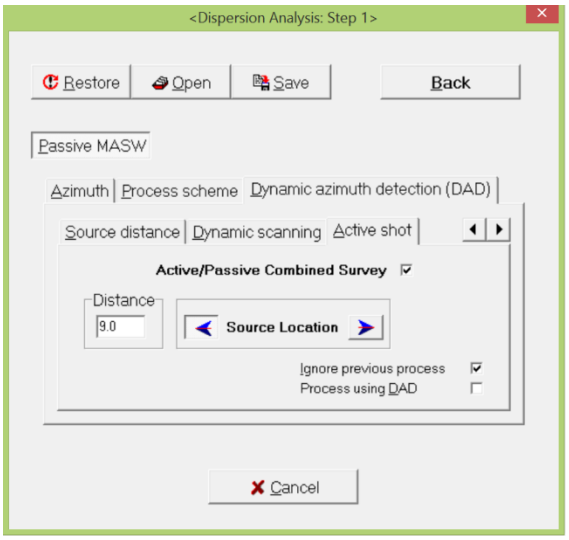

The "Trial distance option" determines whether a dynamically changing interval of distance (i.e., a smaller interval near the survey location) is used or a constant interval is used during the source point detection. Usually, this option makes little difference in result.




The "Length of subrecord (ms)" determines the time length (ms) of individual subrecords created by dividing the long input record. The default value is determined based on the total recording time of the input record. The "Overlapping window on top and bottom (ms)" is the time length (ms) at the beginning and ending parts of one subrecord that overlaps with corresponding parts of the previous and next subrecords, respectively. The "Min. S/N to accept subrecord (%)" sets the minimum signal-to-noise ratio (S/N) of the detected (strongest) surface wave event in one subrecord to be used to construct the dispersion image. If the detected S/N is lower, then the particular subrecord is ignored during image construction.




If checked, the "Active/Passive Combined Survey" option will enable the manual specification of source orientation and distance for the active portion of the record (e.g., 0-2 sec portion). Assuming the channel number increases from left to right, depressing the left arrow indicates the forward orientation of source. If input seismic file has been properly coded for the survey type ("Combined Survey") during the source/receiver (SR) setup procedure, then the correct information about source encoded in the data will be used regardless of the information provided in this tab.




# 8. References

Aki, K., 1957, Space and time spectra of stationary stochastic waves with special reference to micro tremors: Bull. Earthq. Res. Inst., v. 35, p. 415-456.

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Park, C. B., and Miller, R.D., 2008, Roadside passive multichannel analysis of surface waves (MASW): Journal of Environmental & Engineering Geophysics, v. 13, no. 1, p. 1-11.

Park, C., R. Miller, D. Laflen, N. Cabrillo, J. Ivanov, B. Bennett, and R. Huggins, 2004, Imaging dispersion curves of passive surface waves [Exp. Abs.]: Soc. Expl. Geophys., p. 1357-1360.

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