

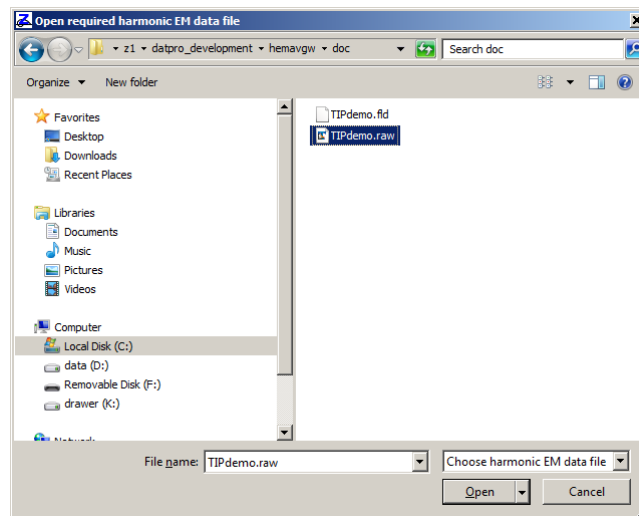
HEMAVGW Documentation

updated 3/Feb/10 by Scott MacInnes

Hemavgw is a frequency-domain data averaging and quality-control utility program that reads harmonic-frequency electromagnetic data (HEM) field data from Zonge GDP raw, fld, or zdb files. It averages generic EM data acquired with the GDP CR program for surveys that do not fit into one of the established IP survey configuration, such as vector or tensor IP surveys or MMR. The program includes a Review Data option for interactive quality control while viewing the data in pseudosections or point-by-point in real-versus-imaginary or phase-versus-frequency plots. **Hemavgw** saves the averaged data in an “avg” file. Unaveraged data are saved in a “zdb” (“Zonge data base”) file, which **Hemavgw** can re-read to revisit data skipping decisions. {Zonge **zdb** and **avg** files have the same format, but use a different file-name extension to distinguish between unaveraged repeat data and averaged data for which all duplicate readings have been merged.} **Hemavgw** reads and writes survey configuration and processing control files from **mde** files, making it easier to duplicate a specific processing sequence when processing multiple GDP CR data files.

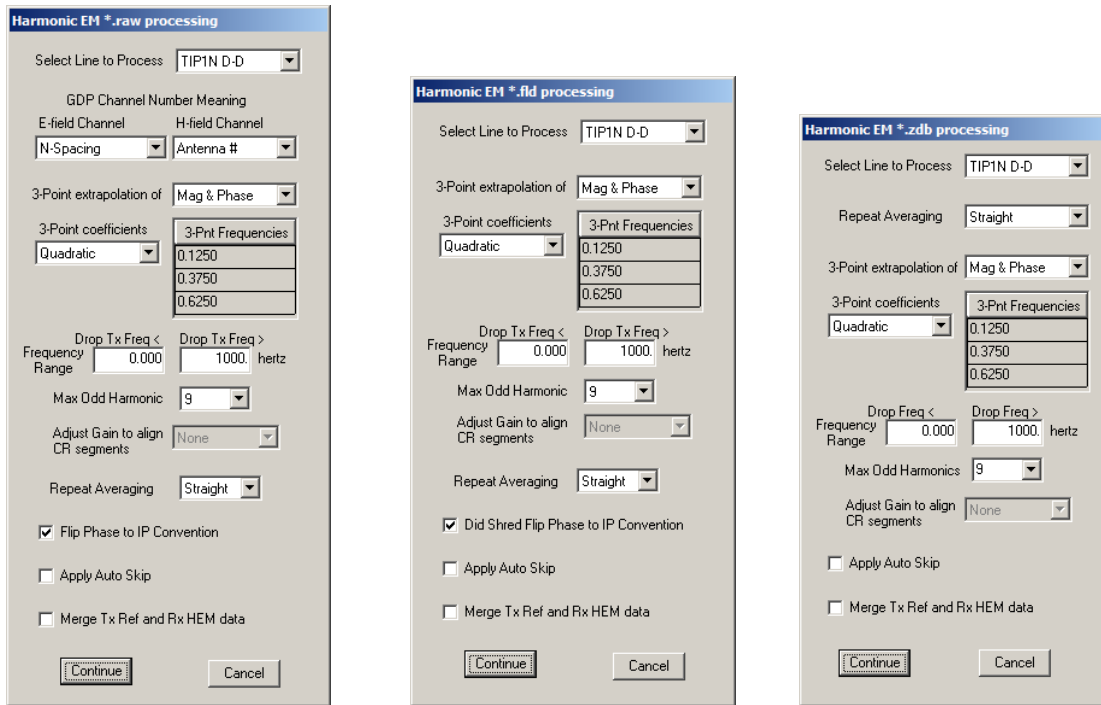
Start **Hemavgw** by running it from the command line, the windows start menu or with a short cut icon. **Hemavgw** first reads default processing control parameters from hemavgw.ini (if it can find it in the directory holding hemavgw.exe). It will then open a full size window and show a file selection dialog. Select an appropriate **raw**, **fld**, or **zdb** file holding harmonic EM data and click on the **Open** button to start processing. Click on the **Cancel** button to abort **Hemavgw**.

Open File Dialog



After getting an input data file name, **Hemavgw** searches for an optional **mde** file with the same file-name stem as the input harmonic EMdata file. If it finds a **mde** file with the right name, it reads it and updates default survey configuration and processing control values based on the **mde** file contents. It then opens the input data file, counts the data and builds a list of line numbers. It shows a dialog to confirm processing control settings and, if the input data file includes multiple lines, to select the line number to be processed.

Processing Control Dialogs



Hemavgw shows either a raw, fld or zdb processing control dialog, depending upon the input file type. Processing control for harmonic EM data input from raw or fld files is similar, but raw file input includes options for specifying how to interpret GDP channel numbers, while fld file input uses station numbers calculated by the legacy program *shred.exe* when it creates fld files from raw files. All processing control dialogs include a field showing a list of line numbers present in the input data set. **Select Line to Process** field allows input from raw or cac files holding data for multiple lines. Dipole-dipole, pole-dipole, pole-pole, Schlumberger data are processed one line at a time, so that the data can be reviewed as a pseudosection. Multiple lines can be processed for Gradient or LabRock input.

For raw files, **GDP Channel Number** options Stn Number, Stn # Offset, N-spacing or Antenna # set the interpretation of the GDP channel number field. N-spacing is the default option for electric-field components, while station-number is the default for magnetic-field components. The station number option uses the GDP channel number as the lower numbered end of a dipole or the station number at a roving pole electrode. For magnetic field components the station number is the coil or magnetic field antenna location. Default option **N-spacing** uses values from each analog input channel's number as n-spacing value, mirroring GDP array conventions. Option n-spacing offset, multiplies the GDP channel number by the GDP A-Space value to get a station number offset that is added to the GDP Rx value. For Stn # Offset, the GDP channel number is interpreted as an offset which is added to the GDP Rx field value to calculate a Rx loop station number. Option Antenna # is used for magnetic field components and uses the GDP channel number as an antenna ID number, so that antenna calibrate values can be recovered to correct data for the antenna's frequency-domain response. The antenna # option will be implemented in future versions of *Hemavgw*, to allow the processing of **B**-field data acquired with specialized antennas.

3-Point Extrapolation fields are used to remove inductive electromagnetic effects. 3-point extrapolation fits a smooth curve to data at the three lowest frequencies, and then extrapolates the curve to 0 hertz to get an estimate of the phase response with frequency-dependent inductive EM effects removed. Extrapolating real and imaginary complex resistivity components is usually a little more effective at removing inductive coupling effects than extrapolating magnitude and phase values. However, if there is any time synchronization error between the transmitter and receiver clocks, 3-point extrapolation of magnitude and phase will remove it. The default **3-Point Coefficients** option is Quadratic, which extrapolates a quadratic polynomial curve fit to data for the first, third and fifth harmonic frequencies to 0 hertz. Two alternatives are Coggon 1.5 and Coggon 2.5 extrapolation coefficients, which are derived from an approximation to a half-space inductive coupling equation (Coggon, 1984, New three-point formulas for inductive

coupling removal in induced polarization, Geophysics, v49, p307-309). The Coggon extrapolation coefficients sometimes work better than the default quadratic polynomial extrapolation, but they are not always an improvement. A fourth option is **Custom Freq**, which allows selection of the three frequencies used for 3-point extrapolation. Harmonic frequency data amplitude drops in proportion to harmonic frequency order, so higher order harmonic data are noisier. In areas with low signal to noise, it can help to acquire CR data with three transmitter frequencies, like 0.125, 0.25 and 0.5 hertz. The Custom Freq option can then be used to specify 3-point extrapolation of the 0.125, 0.25, 0.5 hertz first harmonic data in order to get the cleanest possible 0 hertz 3-point values.

Two fields can be used to clip spectral CR data by transmitter frequency. The **Frequency Range** fields can be edited to put upper and lower limits on the transmitter frequencies processed by *Hemavgw*. A third frequency control field is Max Odd Harmonic, which is the menu field allowing selection of the maximum harmonic frequency 5, 7 or 9. Fourier transforms of the IP transmitter waveform produces a series of odd harmonics. Higher order harmonics have less signal strength and become increasingly noisy. Lowering the maximum harmonic frequency limit can be used to drop high order harmonic data that are too noisy to be useful. 1st, 3rd and 5th harmonic data are always retained for use in the three-point extrapolation.

When data are acquired with multiple transmitter frequencies, there are sometimes small offsets between each segment of 1st through 9th harmonic data. The offset is usually most visible in the in-phase and magnitude values. A dialog field labeled **Adjust Gain to align CR segments** is provided to correct CR data segment offsets when multiple transmitter frequencies were used during data acquisition. Selecting “None” leaves the original data unchanged. “Minimal” adjusts the real part of the offset between data segments when transmitter current or GDP gains have changed. “All Real” adjusts the real part of the offset between all data segments. The most complete correction is provided by “Real & Imag”, which adjusts both the real and imaginary (in-phase and out-of-phase) offsets between CR data segments.

When there is only one transmitter frequency in the data set, the *Hemavgw* processing control dialog fields **3-Pnt Frequencies** and **Adjust Gain to align CR segments** are grayed out indicating display only, and can not be changed. They are accessible for editing when there are multiple transmitter frequencies in the current data set.

Repeat Averaging can be Straight or Robust. “Straight” averaging gives each repeat value the same weight, an averaging method which works well so long as the background noise level is fairly constant. “Robust” averaging helps when there are at least three repeat values for each reading (more than three repeats/reading is preferable). Robust averaging down-weights outlier data, which can be useful if there are lightning spherics present during data acquisition and if four or more repeats are acquired for each reading. Checking **Average |Vp|** takes the absolute value of Vp values before averaging, so that any hookup polarity errors are erased.

The **Apply Auto Skip** check box turns the Auto Skip function on and off. It is turned off by default, and can be applied during data input, by checking the Apply Auto Skip check box, or later via an option on the main menu.

By convention, harmonic EM phase value signs are reversed for IP surveys to get positive IP phase values for in-line IP survey configurations. The EM convention is to leave the phase value sign unchanged. The **Flip Phase to IP Convention** check box turns phase value sign (and imag(EM) value sign) reversal on or off. *Hemavgw* saves the keyword record \$HEMAVGW:Phase.Flip=Yes or No in its output zdb and average files to record the data's phase sign convention.

Merge Tx Ref and Rx HEMdata is an option to merge transmitter reference and receiver complex resistivity data measured with two different, but synchronized GDP-32 receivers. If the option is checked, *Hemavgw* will look for transmitter reference data in a comma-separated-value file with the file name extension *TxRef.csv. See the file format appendix for a description of *TxRef.csv files.

After repeat data are read from the input file, *Hemavgw* shows a Harmonic EM Survey Configuration dialog to verify survey configuration parameters.

Survey Configuration Dialog

The dialog box contains the following fields and sections:

- Project:** TIP Data Sample 1
- Area:** (empty)
- for:** Zonge Engineering
- by:** Zonge AK
- Job #:** D1001
- Date:** 3-09-16
- IP Array:** D-D
- Length Units:** m
- Line Name:** TIP 1 N
- Line Number:** 1.0
- Line Azimuth:** 90.0
- Line Type:** Straight

| Station Number Rescaling | | | | E-Dipole Length (m) | H-Antenna Area (m ²) | Rx Component |
|--------------------------|-----------|-----------|------------|---------------------|----------------------------------|--------------|
| Stn # | Beginning | Increment | m/stn# | | | |
| GDP | 1001.00 | 1.00 | 6.43087E-2 | 100.00 | 1.0000E+4 | 90.0 |
| Rescaled | 1001.00 | 1.00 | 6.43087E-2 | 100.00 | 1.0000E+4 | 0. |

Additional parameters:

- vertical Z:** 1.0000E+4
- z+:** up

File handling options:

- Save HEM data in .avg file
- Output File Name:** TIPdemo
- Browse for strn file:** tipdemo.stn

Fields in the upper left section of the dialog store descriptive survey annotation information. **Project** name, **Area**, **for**, **by** and **Job #** fields store arbitrary text strings that are stored in *zdb* and *avg* files for descriptive documentation. **Date** records the data acquisition date. **Length Units** can be m or feet.

IP Array is a list box showing abbreviations for common IP survey configurations, which affect the default interpretation of n-spacing values when calculating receiver station numbers from GDP raw files.

- **D-D** indicates Dipole-Dipole, an in-line survey with uniform length transmitter and receiver dipoles. Both transmitter and receiver dipoles are aligned along a single survey line.
- **P-D** indicates Pole-Dipole, an in-line survey with one transmitter electrode fixed at a remote location and one roving Tx electrode moving along the survey line. Receiver dipoles are assumed to have a uniform length and be aligned along line.
- **P-P** means an in-line Pole-Pole array with Tx and Rx remote fixed electrodes and in-line roving Tx and Rx electrode poles.
- **Grd** array means a Gradient array with a large fixed transmitter bipole, and in-line arrays of uniform length receiver dipoles moving along lines parallel to the Tx bipole.
- **Sch** represents a Schlumberger resistivity sounding, with short receiver dipoles centered in large transmitter bipoles.
- **D-H**, or Down-Hole, is the most versatile array. The GDP Tx number is used as a key to a list of transmitter wire endpoint coordinates in a txc file (see file formats in Appendix A). Each transmitter can have multiple wire segments both on the surface and down hole. Similarly, receiver station values are used as a key to coordinates in a station file, and can represent either surface or down-hole measurement locations.
- **Lab** represents LabRock or Laboratory Rock sample measurements. Resistivity and IP properties are measured on hand-specimen sized rock samples. Tx and Rx values are used as sample identification numbers.

Line Name is a string of up to 16 characters that can be used to hold descriptive line labels like 200E or Drill Hole 001.

Line Number is a floating point line number, suitable for use in a Geosoft montaj *gdb* database or as a coordinate value in a curvilinear (line, station) coordinate system.

Line Azimuth is a line bearing indicating the direction of increasing station numbers in degrees east of north.

Line Type can be Straight, Meander or Points. Most IP survey configurations use in-line arrays, so **Line Type** field is set to “Straight” for all arrays except D-H. The D-H (Down-Hole) array includes general configurations like vector IP, where stations can be point measurements at a set of randomly distributed locations, so all three line types are allowed for D-H arrays. For Straight and Meander lines, *Hemavgw* can use along-line interpolation to locate electrodes, but for the Points line type, *Hemavgw* uses dipole length and Ex azimuth to position the second receiver electrode.

It is not uncommon to decide that the station number system should be changed after data acquisition is complete. *Hemavgw* includes parameters for scaling and shifting the GDP station numbers used during data acquisition, to “client” station numbers suitable for use on plots and in deliverable data files. By default, there is no rescaling, but **Station Number Rescaling** values can be modified to rescale station numbers. **GDP Station Numbers** indicate the station number system used during data acquisition, while **Rescaled Station Numbers** are the possibly different station numbers needed for final data files and plots. Station number origin and increment values are specified for GDP and rescaled or client station numbers. Station number increments must be non-zero, but negative increment values can be entered to reverse station number order. Station numbers are expected to be proportional to distance along line. The m/stn # field is a scaling factor that scales station numbers to meters.

E-Dipole Length and H-Antenna Area fields are used to specify the length of electric field dipoles and the effective surface area of magnetic field antenna respectively. By convention Ex and Hx are along-line components, while Ey and Hy are perpendicular to line. Vertical magnetic field measurements are indicated by Hz. Raw and fld file component “ON” labels are considered to be the same as “Ex”. Down-hole electric field measurements are considered to be “along-line” and should be labeled as ON or Ex. Z can be either positive up or positive down, which controls the relative orientation of positive X and Y in map view. X components are along line and Y components are across line, and (X,Y,Z) always define a right-handed coordinate system. If Z is positive up, then positive Y is 90 degrees counterclockwise of positive X in map view. If Z is positive down, then Y is 90 degrees clockwise from positive X in map view.

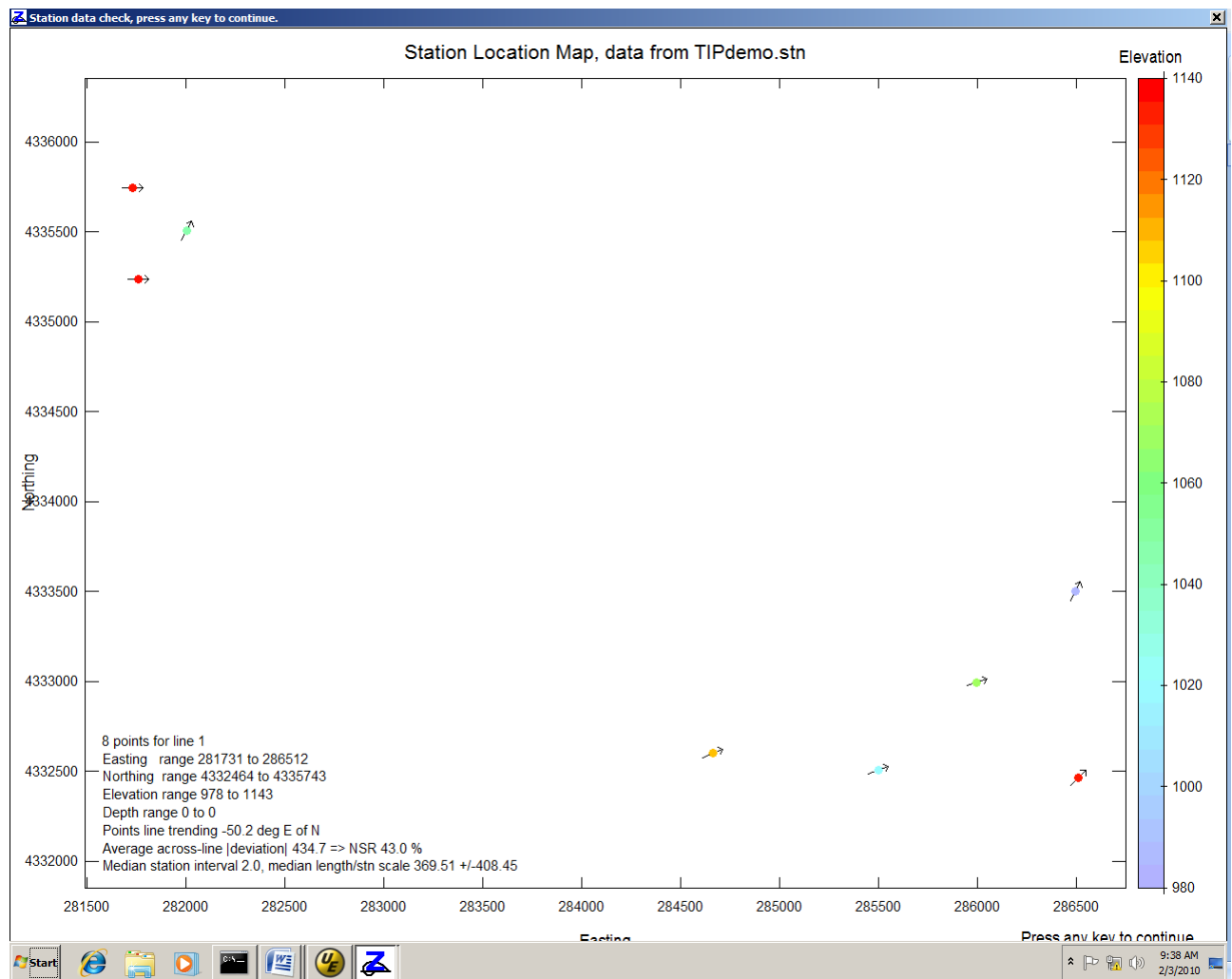
Hemavgw includes fields for fixed electrode coordinates, so that remote electrode locations can be specified. Remote electrode locations are specified in along-line X, across-line Y and depth Z coordinates. Multiple remote transmitter electrode locations can be specified by putting \$Tx.XYZ2 keyword records in the raw file (see raw file documentation in the File Format appendix).

The **Browse for Stn File** button can be used to bring up an Open File dialog to select a stn file and import station coordinates. By default, *Hemavgw* looks for a stn file with the same file-name stem as the input data file, but a different file name can be selected for stn file input. Station files hold tabular data with required columns of station, east, north and elevation (and optional columns of heading, pitch, roll, depth and line). If a stn file is selected for input, the stn file tables are interpolated on station number to recover geographic coordinates for each CR data station. The optional depth column can be used to map line and station number to down-hole coordinates. The optional line column is used when the station file includes coordinates for multiple lines. The optional heading, pitch and roll columns are sometimes used for reconnaissance or tensor IP surveys where EM component orientation may be different for each station.

Hemavgw always saves the unaveraged data to a zdb file to allow multi-session data processing. It saves averaged data to the Zonge avg file format by default, but avg file output can be turned off by un-checking the **Save HEM data in avg file** check box. The output file name can be edited in the Output File Name field.

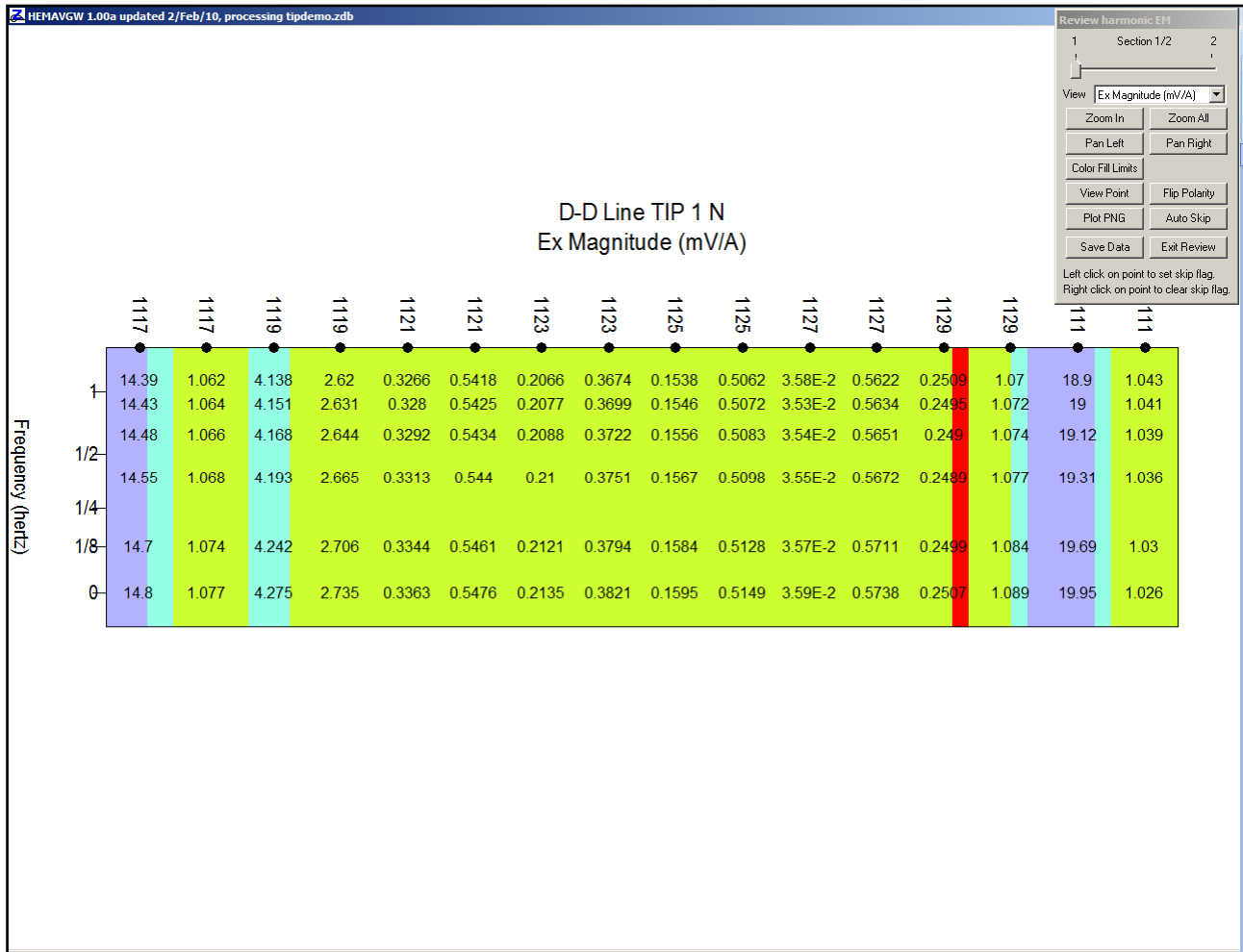
After survey configuration values have been verified, click on the **Continue** button to go to the next processing step and review the data or select **Cancel** to abort data input.

If a stn file has been selected in the Survey Configuration dialog, *Hemavgw* will read the station file coordinates and show a station location map.



Lines are most often parallel to rectilinear grid coordinates, but may be used to represent a group of stations like the scattered measurement locations shown in this sample tensor IP (TIP) data set. Small circles represent station locations, with their color indicating elevation and a small arrow indicating the orientation of field array's x component. In this TIP example, the field (Ex,Ey) arrays are rotated to different orientations to avoid brush during array setup. Station files may include data for multiple lines, consistent with multi-line gradient or down-hole data sets. See the stn file format documentation in Appendix A for a more complete description of stn files.

Review Data Dialog



Review Data shows all data in a generic EM pseudosection or as individual data point transients. Since *Hemavgw* is used for unorthodox EM surveys, it makes no assumptions about the actual survey configuration and uses a generic pseudosection format with station numbers along the top axis and frequency on the vertical plot axis. Posted numbers indicate individual data values with color-filled contours showing the overall data value pattern. Black text shows data point values that have not been skipped, while gray pseudosection text indicates skipped data. A pseudosection data point can be skipped by pressing the left mouse button while the mouse cursor is over the bad data point. The skip flag can be cleared from a point with a right mouse button click while the mouse cursor is over the grayed out data value.

A small pop-up dialog provides options for Data Review plot control. Each pseudosection plot shows data for one electromagnetic field component. If the data set includes more than one component, a track bar along the top of the dialog controls which EM component is displayed in the pseudosection plot.

The **View** field shows a list of data types available for display, Magnitude, Phase, Real, Imag data or error values. Electric field data are scaled to mV/A while magnetic field data are scaled to nT/A.

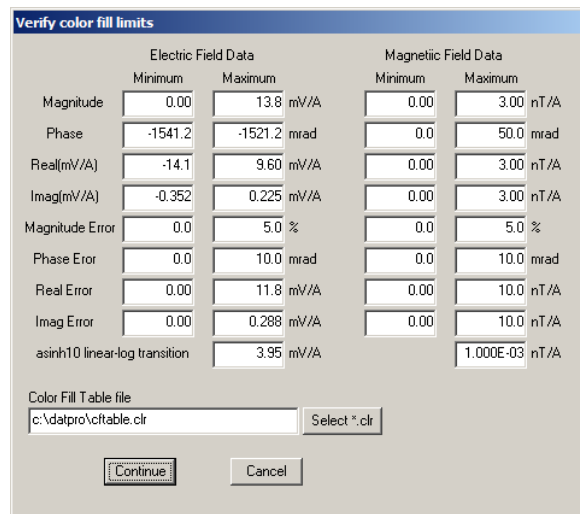
To see more detail in a long line, **Zoom In** allows magnification of pseudosection details. *Hemavgw* will show a magnifying glass cursor when **Zoom In** has been clicked. Position the cursor on one corner of the area of interest and “left click” (depress the left mouse button) to anchor a corner of the **Zoom In** selection rectangle. *Hemavgw* will then show a + shaped cursor and a green rubber-band box indicating the extent of the selection rectangle. Move the mouse cursor to adjust the selection box to include the area of interest and left click again to see a magnified pseudosection

plot. The **Pan Left** and **Pan Right** buttons allow lateral movement when the pseudosection plot is magnified. Clicking on the Review Data dialog **Zoom All** button restores the pseudosection plot to a full scale view.

Data point polarity can be changed by clicking on the **Flip Polarity** button, which will change the mouse cursor to a double arrow, \leftrightarrow . A left click anchors one corner of a rubber band box, and **Hemavgw** will then show a + shaped cursor and rubber band box outlining the extent of the selection area. A second left click anchors the second corner of the selection box, and the polarity of all data within the selection is reversed. Polarity flips are not visible when the pseudosection is showing magnitudes, but polarity is visible in the other pseudosection plot types.

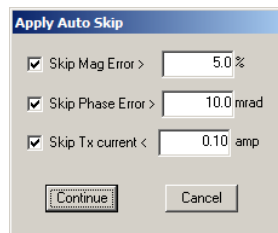
Plot PNG exports the current pseudosection plot to a png (portable network graphics) raster image file. The png plot file will have text appended to its file name to indicate the pseudosection data type.

The **Color Fill Limits** button can be used to adjust the color fill limits, popping up a dialog with the color fill range for each pseudosection parameter type.



Verify Color Limits dialog fields allow control of the minimum and maximum color fill range. To accommodate large variation, magnitude, real and imaginary data values are transformed with the $\text{asinh}_{10}(\text{data}/\text{scale})$ function for pseudosection color fill. $\text{Asinh}_{10}(x)$ looks like x for $x = 0$ to 1 and looks like $\log_{10}(x)$ for $x > 1$, allowing representative color fill across at large range. The asinh_{10} linear-log transition fields controls the asinh_{10} linear-to-log break point. The Color Fill Limits dialog also allows selection of an alternative color fill spectrum file (*.clr). Clr files use the Surfer “Color Spectrum File” format, an ASCII format that specifies a table of (percent, red, green, blue) values, where percent can vary from 0 at the color fill minimum to 100 at the color fill maximum, and red, green and blue are integer values between 0 and 255 representing color intensity.

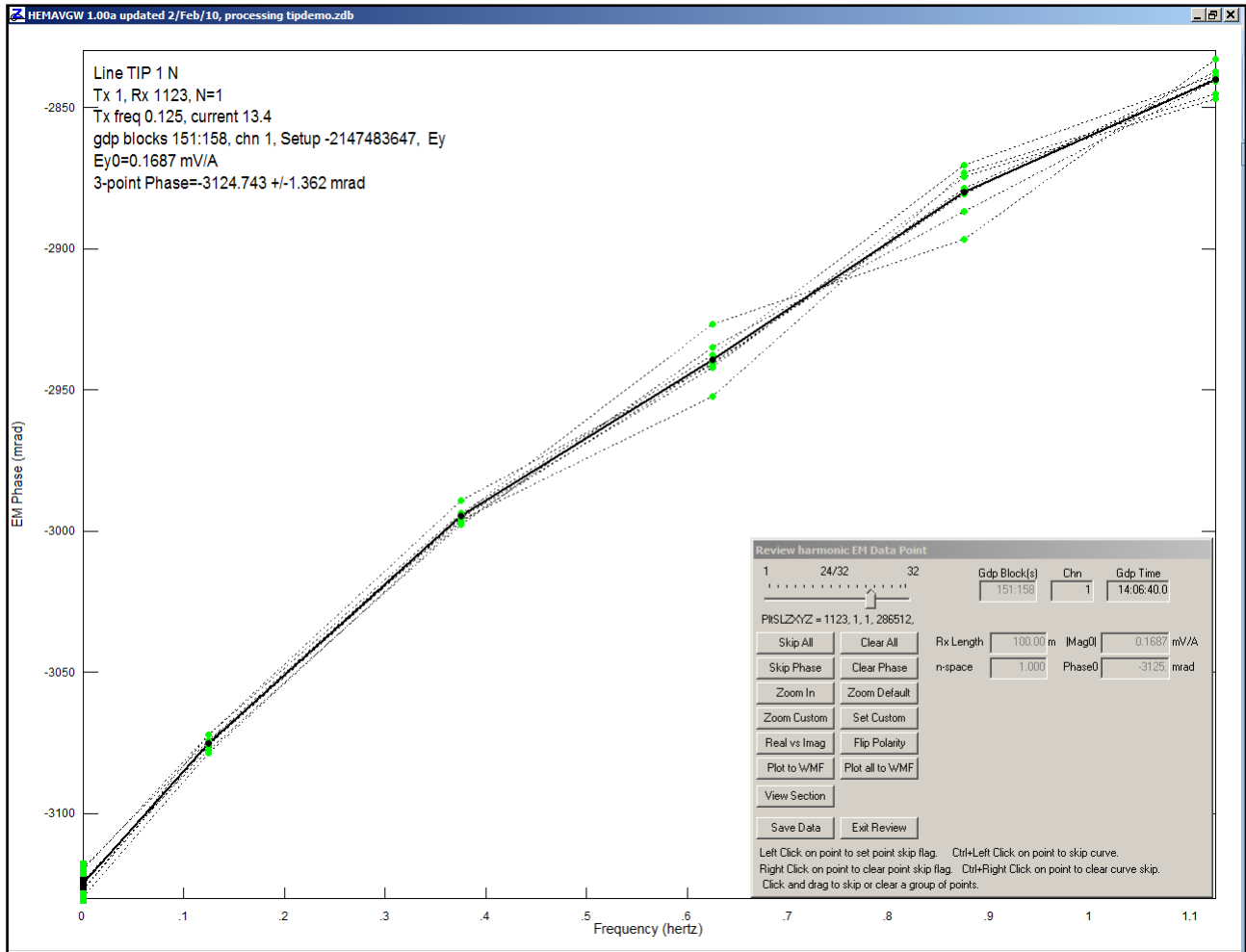
Auto Skip button provides a quality control short cut.



Auto Skip sets averaged data skip flags if selected criteria pass user selected thresholds. Check boxes turn Auto Skip criteria on or off. A check mark indicates that the criteria will be used to set skip flags. **Skip Mag Error** > skips averaged data whose magnitude error exceeds the percent error threshold in the upper right numeric field. **Skip Phase Error** > skips averaged data with phase error exceeds the specified mrad threshold. **Skip Tx current** < can be used to

skip averaged data when the transmitter current falls below the specified threshold in amps. The Skip Tx current < criteria should not be used on LabRock data, because LabRock currents are usually quite small, less than a milliamp. The Continue button applies the Auto Skip criteria to the averaged data, while Cancel aborts Auto Skip without setting any skip flags. Auto Skip is also available as an option on the main menu (which is described later in this documentation). The main menu also has a Clear Skip Flags option to undo Auto Skip and any manually set averaged data skip flags.

To review data on a point by point basis, click on the **View Point** button. The mouse cursor changes to a green square. A left click with the square over a pseudosection data point selects the point to show as a phase versus frequency “Bode plot” or real versus imaginary data “Nyquist plot”.



Bode and Nyquist plots show frequency-domain harmonic EM data one point at a time. Point plots provide a more detailed view of the data and allow quality control skipping of individual repeat values. Unskipped repeat data points are indicated by small green circles, while skipped data are indicated by a red circle. Averaged data points are indicated by a slightly larger black circle. If all of the repeat data for a particular time window are skipped, the corresponding averaged data point is skipped, and is plotted as a gray circle. Data point groups can be skipped by pressing the left mouse button to anchor one corner of a selection box, and then moving the mouse with the button held down to locate the second selection box corner. All data within the selection box is skipped when the left mouse button is released. Similarly, skip flags can be cleared from groups of data points by setting the corners of a selection box with the right mouse button.

The three-point extrapolation to 0 hertz is shown by posted squares. Three-point values can be skipped or cleared in the same way as other phase values.

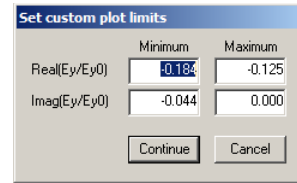
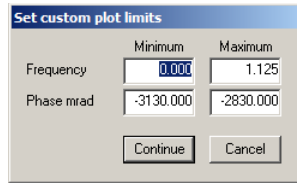
An entire repeat curve can be skipped with a Ctrl + left_click while the cursor is over one of the curve's points. Conversely, Ctrl + right_click can be used to clear skip flags on an entire repeat measurement curve.

The small pop-up plot control dialog can be repositioned by putting the mouse cursor on its blue title bar, and then holding down the left mouse button while moving the mouse. The plot control dialog sometimes obscures part of the plot curves, but it can be dragged to a different position.

A plot control dialog for curve data review allows movement between stations via a track bar. If the mouse cursor is in the plot window, the display can be advanced from station to station by pressing the right arrow key, the N (N for Next)

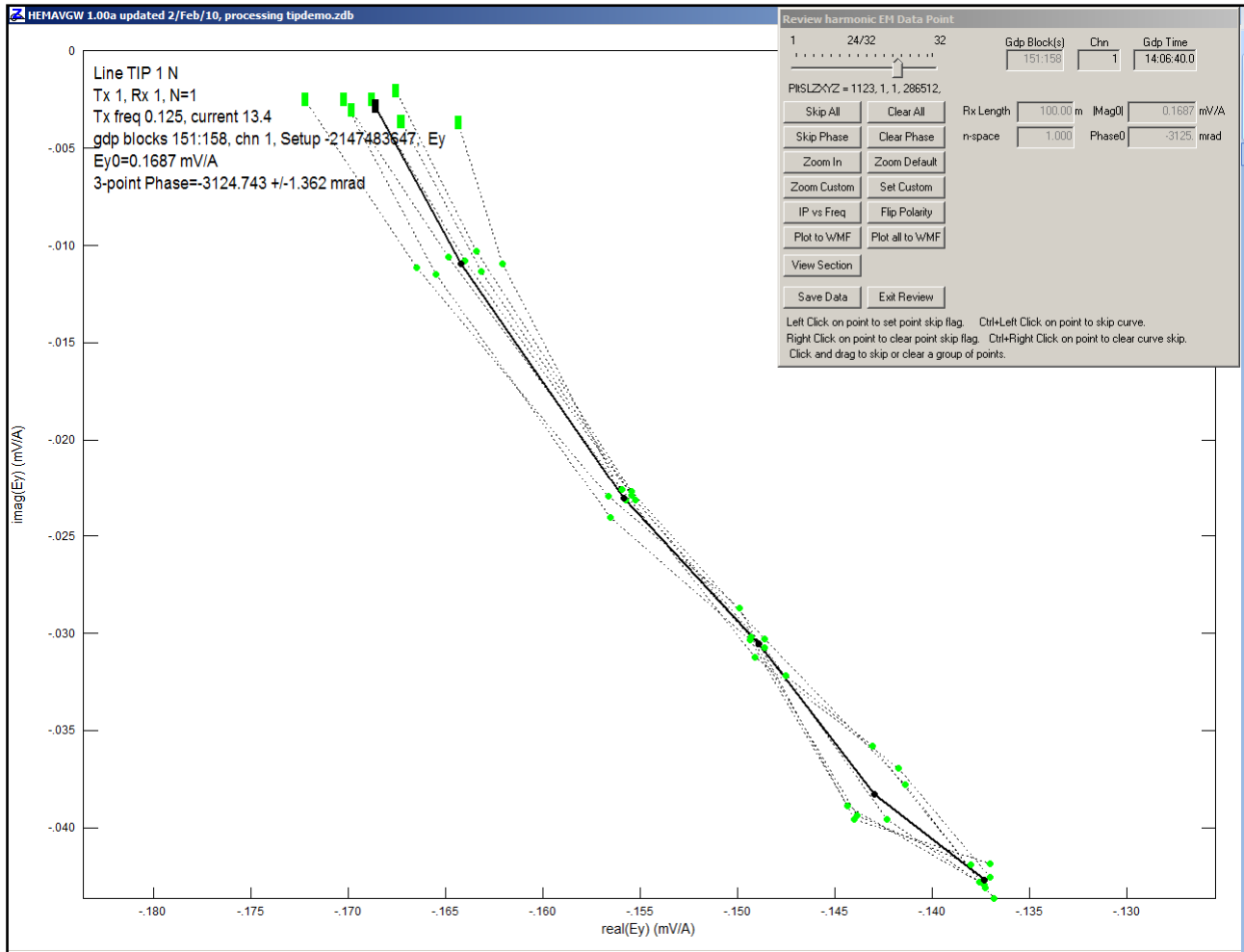
key, or by rolling the mouse scroll wheel down. The transient curve plot can be moved to a previous station by pressing the left arrow key, the P (P for Previous) key, or by rolling the mouse scroll button up. The **Skip All** button skips apparent resistivity and IP data for the current, while **Clear All** clears skip flags from both apparent resistivity and IP phase values. **Skip Phase** skips all of the phase data associated with the current data point, but leaves the magnitude values unskipped. The phase values can be cleared with the **Clear Phase** button.

The **Zoom In** button changes the mouse cursor to a magnifying glass. Position the mouse cursor on one corner of the area of interest and “left click” (depress the left mouse button) to anchor a corner of the **Zoom In** selection rectangle. **Hemavgw** will then show a + shaped cursor and a green rubber-band box indicating the extent of the selection rectangle. Move the mouse cursor to adjust the selection box to include the area of interest and left click again to see a magnified pseudosection plot. Plot limits can be customized with the **Set Custom** button.



Customizing plot limits provides an alternative to the default view. You can jump between the default and custom plot extents with the **Zoom Default** and **Zoom Custom** buttons.

Point data review includes Nyquist plots of Real(mV/A) versus Imag(mV/A) as an alternative to the phase versus frequency Bode plots. Click on the Real vs Imag button to move from the Bode to a Nyquist data point plot.



Nyquist plots show the same information in a different manner. Individual repeat measurements are still shown by dotted line curves connecting small green or red points. Square symbols indicate three-point values at 0 hertz.

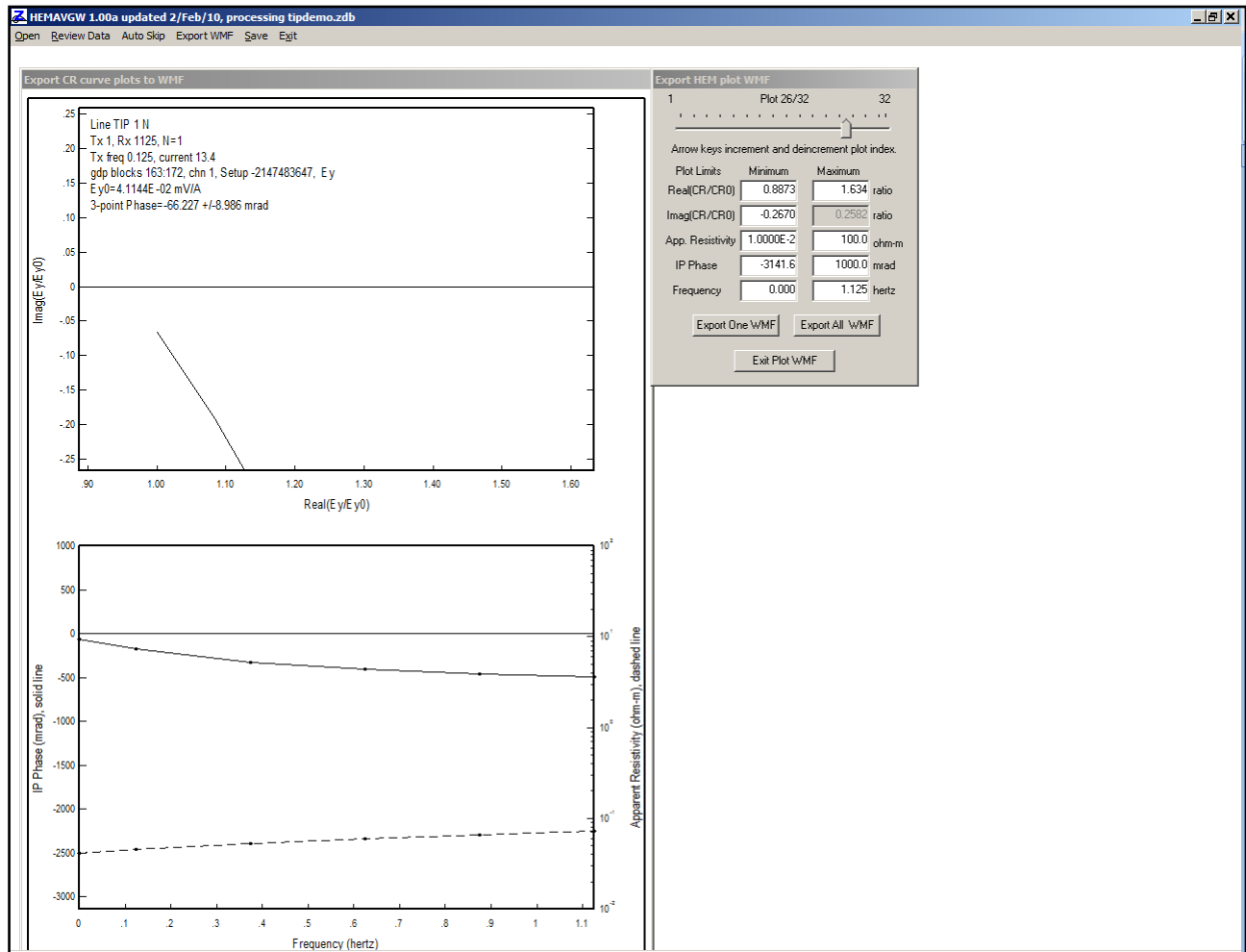
The **View Section** button returns Data Review to the pseudosection data review display. **Save Data** writes unaveraged data to a zdb file and saves averaged data values in an avg file. Zdb and avg files use the same ASCII file format, although they hold different data set types. **Exit Review** closes the Review Data option and shows a blank window with a menu strip along the top.

Main Menu Options

Hemavgw displays a strip of menu choices after the initial data review is finished. **Open** brings up the Open File dialog to select a new input data file name. **Review Data** invokes the quality control pseudosection plot described in the previous section of this documentation. **Auto Skip** is a pop up menu category that includes the two menu options Apply Auto Skip and Clear Skip Flags. **Apply Auto Skip** menu option brings up the same Auto Skip control dialog as the Pseudosection Data Review, Auto Skip button described earlier in this documentation. **Clear Skip Flags** clears all skip flags from the averaged data. It should be used with caution since it can undo skip flags set manually during Pseudosection Data Review. **Save** saves the current data to zdb and avg files, while **Exit** closes **Hemavgw**.

The **Export WMF** menu selection pops up a two-panel plot with averaged Real(E/E0) versus Imag(E/E0) in the top panel and averaged apparent resistivity and phase versus frequency in the lower panel. The combined plots can be exported to wmf files one at a time with the **Export One WMF** button, or all at once with the **Export All WMF**

button. Export WMF provides a way to display results on a point by point basis, and is most often used to present LabRock results.



The Export CR plot WMF control dialog includes fields for manual control of plot limits. The **Exit Plot WMF** button closes the plot window and returns the program to the main menu.

File Formats

Hemavgw.ini: survey configuration and processing control default values

Hemavgw.ini is used to set default survey configuration and processing control values. It is an ASCII file that can be edited with a generic text editor. Each line is a keyword record with a \$program:keyword=value(s) or \$keyword=value(s) format. There may multiple comma-separated values after some keywords. For example TBin.Begin and TBin.End are followed by long list of comma-separated values. Comment lines beginning with the character ";", "!", "/" or "\" can be anywhere within an ini file. Blank lines and comment lines are skipped while ***Hemavgw*** is reading ***ini*** files.

Hemavgw.ini is primarily used to store ***Hemavgw*** processing control parameters, but generic survey configuration keyword records may be pasted into the ini file to control ***Hemavgw*** default values. ***Hemavgw*** updates the \$HEMAVGW: records in ***Hemavgw.ini*** with its current processing control values. Any additional keyword records in ***Hemavgw.ini*** are saved as is.

Listing of sample ***hemavgw.ini***

```
-----  
$HEMAVGW: Avg.Type=Robust  
$HEMAVGW: Phase.Flip=Yes  
$HEMAVGW: 3Pnt.Type=Mag & Phase  
$HEMAVGW: 3Pnt.Coeff=Quadratic  
$HEMAVGW: 3Pnt.Freq=0.125,0.375,0.625  
$HEMAVGW: 3Pnt.Wgt=1.875,-1.25,0.375  
$HEMAVGW: TxFreq.Min=0  
$HEMAVGW: TxFreq.Max=1000  
$HEMAVGW: MHAFreq=5  
$HEMAVGW: Ch.NumberType=N-Spacing, Antenna #  
$HEMAVGW: Skip.Auto=No  
$HEMAVGW: Skip.OnARerr=Yes  
$HEMAVGW: Skip.OnIPerr=Yes  
$HEMAVGW: Skip.OnTxAmp=No  
$HEMAVGW: Skip.ARerrCeiling=5 %  
$HEMAVGW: Skip.IPerrCeiling=10 mrad  
$HEMAVGW: Skip.TxAmpFloor=.1 amp  
-----
```

Averaging

HEMAVGW: Avg.Type = enumeration, {Straight,Robust}

Phase sign convention

HEMAVGW: Phase.Flip = boolean, yes=flip phase to IP sign convention

Three-point extrapolation

HEMAVGW: 3Pnt.Type = enumeration, 3-point extrapolation data {Real & Imag, Mag & Phase}
HEMAVGW: 3Pnt.Coeff = enumeration, 3-pnt coefficients {quadratic, Coggon 1.5, Coggon 2.5, Custom Freq}
HEMAVGW: 3Pnt.Freq = float, 3-point frequencies (hertz)
HEMAVGW: 3Pnt.Wgt = float, 3-point data weights

Data filtering

HEMAVGW: TxFreq.Min = float, minimum Tx frequency to include (hertz)
HEMAVGW: TxFreq.Max = float, end maximum Tx frequency to include (hertz)
HEMAVGW: MHAFreq = enumeration index, maximum harmonic to use {1=1,2=3,3=5,4=7,5=0}

GDP

HEMAVGW: Ch.NumberType = enumeration {Stn # Offset,N-Spacing,N-Space Offset,Antenna #}

Auto skip control

\$HEMAVGW:Skip.Auto = boolean, yes=apply Auto Skip on data input
\$HEMAVGW:Skip.OnARerr = boolean, yes=skip if apparent resistivity error > ceiling
\$HEMAVGW:Skip.OnIPerr = boolean, yes= skip if IP error > ceiling
\$HEMAVGW:Skip.OnTxAmp = boolean, yes=skip if Tx current < floor
\$HEMAVGW:Skip.ARerrCeiling = float, apparent resistivity error ceiling (%)
\$HEMAVGW:Skip.IPerrCeiling = float, IP error ceiling (mrad)
\$HEMAVGW:Skip.TxAmpFloor = float, Tx current floor (amps)

24-bit cac file processing control (for future use)

HEMAVGW:Process.TS = boolean, yes=process cac file time series data
HEMAVGW:Process.STACK = boolean, yes=process cac file stack data
HEMAVGW:Process.DECAY = boolean, yes=process cac file decay data
HEMAVGW:Process.BINNED = boolean, yes=process cac file binned transient data
HEMAVGW:Stack.Type = enumeration, {Straight,Taper,Robust}
HEMAVGW:Stack.Shape = float, Kaiser window taper (0=rectangular to 5=Gaussian)

Color-fill table file (cftable.clr)

CfTable.clr is an ASCII file specifying the color spectrum to use for color fills. The installation version has a blue-to-red rainbow spectrum, but cftable.clr can be customized to suit individual tastes. CfTable.clr uses the Golden Software Surfer format, so sample Surfer clr files with different color spectrums can be copied from the ..\Surfer\Samples subdirectory.

Listing of **cftable.clr**:

```
ColorMap 1 1
  0      178      178      255
  25     153      255      255
  50     128      255      128
  75     255      255       0
 100     255       0       0
```

cftable.clr file variables:

Hemavgw ignores the header line “ColorMap 1 1”, but it should be included for compatibility with Surfer.

The remaining numerical records specify range, red, green and blue values for a variable number of anchor points, where

Range = percent between minimum and maximum contoured data (0 to 100),
Red = amount of red color from 0=none to 255=maximum,
Green = amount of green color from 0=none to 255=maximum,
Blue = amount of blue color from 0=none to 255=maximum.

Colors are interpolated between anchor points to get a color-fill spectrum with continuous gradation. Range values should be ordered from low to high with no duplicate values, and should include records for the minimum and maximum range values, 0 and 100.

MDE file - line annotation, survey configuration and data processing control

Hemavgw looks for an optional *.mde file with the same file-name stem as the input data file to get project and line specific default values. MDE files have an ASCII format that is easy to edit and are usually used to set initial survey annotation, survey configuration, and processing control parameters for each survey line. A MDE file consists of one or more “mode” or keyword lines, each of which begins with a "\$" in the first column, optionally followed by a program name and colon ":". The keyword is followed by an equal sign "=", then the value to assign to the associated variable.

Spaces may be included between the elements of the mode line. Spaces in values defined as text will be included as part of the value. Some keywords, like Rx.HPR, take multiple comma-separated values. Annotation text strings should be enclosed in quotes, so that any enclosed commas are not parsed as value field separators. Lines that begin with a leading !, \, / or “ character are interpreted as comment lines and skipped over during mde file input. If a keyword line includes a program name, only the named program will read the record. Including a specific program name identifies which program is to use the associated parameter value. The same \$program:keyword=value(s) and \$keyword=value(s) format is used in mde, ini, zdb and avg files. Programs ignore unknown keywords during input, so new keywords may be introduced without breaking old software.

Sample MDE file listing

```
-----  
$Job.Name = "CR D-D Data"  
$Job.Area = "Zonge Datpro"  
$Job.For = "Zonge AZ"  
$Job.By = "Zonge AK"  
$Job.Number = "110a"  
$Job.Date = 09-06-15  
$Survey.Type = CR  
$Survey.Array = D-D  
$Line.Azimuth = 90  
$Stn.GdpBeg = 0  
$Stn.GdpInc = 300  
$Stn.GdpUnitScale = 0.3048 m/GdpStn#  
$Stn.Beg = 0  
$Stn.Inc = 300  
$Stn.UnitScale = 0.3048 m/Stn#  
$Rx.Length = 300,300 ft  
$Rx.HPR = 90,0,0  
$Unit.Length = ft  
-----
```

Keywords Stn.GdpBeg, Stn.GdpInc, Stn.Beg and Stn.Inc can be used to shift and scale the GDP station numbers used in *.raw or *.fld files to a different set of “client” station numbers suitable for report plots. Note that stn files use client station numbers, since station location information is often provided by the client. Client station numbers are calculated from GDP station numbers using $Stn = (Stn.Gdp - Stn.GdbBeg) * Stn.Inc / Stn.GdpInc + Stn.Beg$. Default values produce no station number shifting or scaling.

| | |
|---------------|---|
| Stn.GdpBeg | = first GDP station number origin (legacy alias StnLow) |
| Stn.GdpInc | = GDP station number increment (legacy alias StnDelt) |
| Stn.Beg | = client station number origin (legacy alias LblFrst) |
| Stn.Inc | = client station number increment (legacy alias LblDelt) |
| Stn.UnitScale | = client station number to meter scale (meters/client_stn_number) |
| Stn.Left | = client station number on left side of pseudosection & section plots |
| Stn.Right | = client station number on right side of section plots |

Stn.Left may be greater than Stn.Right to reverse plot axis station number order

Survey Annotation

Job.Name = string, project name (< 128 char) (legacy alias Project)
Job.Area = string, project area (< 128 char)
Job.For = string, client name (< 128 char) (legacy alias Client)
Job.By = string, contractor name (< 128 char) (legacy alias Company)
Job.Number = string, identifying job label (< 16 char) (legacy alias JobNum, JobNumber)
Job.Date = string, data acquisition date (< 16 char) (legacy alias JobDate)
Line.Name = string, arbitrary line "number" (< 16 char) (legacy alias Line)
Line.Number = float, line number, used for coordinate interpolation
Line.Azimuth = float, azimuth (deg E of N of increasing stn numbers) or string = NnnE bearing format

Survey Configuration

Survey.Type = enumeration, always CR
Survey.Array = enumeration, IP array type {D-D, P-D, P-P, Grd, Sch, D-H, Lab}
Unit.Length = enumeration, length units {m, ft} (legacy alias Units)
Tx.Length = float, Tx dipole length (length units) (legacy alias TxLength)
Rx.Length = floats, X and Y Rx dipole lengths (length units)
Rx.HPR = floats, Rx component orientation (heading, pitch, roll deg)
Roll = 0 => z positive up, roll = 180 => z positive down

STN file - station location and elevation

STN files hold information about station locations in a tabular format with space or comma separated values. A STN file should have at least two entries, corresponding to the first and last stations. Additional entries may be necessary to trace out topographic changes or curved lines. STEMINV assumes that station numbers are related to distance along line. Station number values are used to linearly interpolate (easting,northing,elevation) coordinates for stations that do not have a matching entry in the STN file. If station numbers are scaled by entries in the MDE file, STN-file station numbers should be in the scaled and shifted client station numbers defined by Stn.Beg and Stn.Inc, not the unscaled and unshifted GDP station numbers defined by Stn.GdpBeg, Stn.GdpInc.

Records beginning with a !, “, \ or / character are classified as comment lines and are skipped.
Blank records are skipped.

Some grid coordinate systems, such as UTM coordinates, can generate very large coordinate values. Many programs store station locations as floating-point numbers with seven significant figures. It may be necessary to subtract a constant from large coordinate values in order to allow accurate representation with no more than seven significant figures.

Station files may include optional Heading, Pitch and or Roll columns. A Heading column is often added if surveys include spot soundings where the EM component orientation varies from one station to the next, i.e. reconnaissance or tensor IP surveys. There may also be an optional Depth column, to locate down-hole survey receiver stations with respect to the surface of the ground. A station file may hold data for multiple lines if a Line column is present.

Listing of typical stn file:

```
-----  
Station, Easting, Northing, Elevation, Line, Heading  
1117,      281731,   4335743,    1142,     1,    90  
1119,      281759,   4335236,    1143,     1,    90  
1121,      286498,   4333500,     978,     1,    27  
1123,      286512,   4332464,    1141,     1,    45  
1125,      285998,   4332995,    1071,     1,    72  
1127,      285501,   4332506,    1016,     1,    68  
1129,      284662,   4332600,    1113,     1,    67  
3111,      282003,   4335506,    1045,     1,    28  
-----
```

STN file column definitions:

Station = client station numbers
East = grid east (m or ft, length units specified when STEMINV creates a new std file)
North = grid north (m or ft)
Elevation = elevation (m or ft)
Heading = X component azimuth (deg E of N), optional column
Pitch = X component pitch (deg up from horizontal), optional column
Roll = Z component rotation about X axis (deg clockwise), optional column
Depth = depth with respect to surface for D-H array (m or ft), optional column for D-H surveys
Line = line number, optional column for stn files with multiple lines

GDP-32 ASCII CR Data File (*.raw)

Harmonic EM data are acquired with the GDP-32 CR program, which saves data in ASCII files with a fixed-form block style. Blank lines separate blocks and there are two block types, header and data.

GDP-32 CR Header Block Samples

5713

```
CR 0837 2008-03-12 11:02:31 12.4v D-D 22.6% 33.3 DegC
OPER      Mark TX ID      1 A-SP 200 M
JOB 0813 LINE      IP04 N SPREAD 1 MAV Enabled
1      DiffAmp Notch 60,3-5,9 S/N 466 Passed 1.00000
:      :      :      :      :      :      :      :
:      :      :      :      :      :      :      :
```

1789

```
CR 0826 2009-01-03 0:54:40 12.4v Grd 19.2% 26.1 DegC
OPER      MMG TX ID      1 A-SP 200 M
JOB 0820 Ay      50339 E SPREAD 1 Ax 403160 Bx 411185 MAV Enabled
1      DiffAmp Notch 50,3-5,9 S/N 549 Passed 1.00000
:      :      :      :      :      :      :      :
:      :      :      :      :      :      :      :
```

GDP-32 CR Header block structure

| Line | FIELD_NAME | UNITS | RANGE | TYPE | WIDTH | END |
|--------|------------------------|-------|---------------------|-----------|-------|-----|
| Line 1 | Block Number | # | 0 - 9999 | Integer | 4 | 4 |
| Line 2 | Survey Type | - | ex:"CR " | Character | 4 | 4 |
| | Version Number | # | 0 - 9999 | Integer | 4 | 8 |
| | Skip Flag | - | x or space | Character | 1 | 9 |
| | Date | date | yyyy-mm-dd | Date | 10 | 19 |
| | Time | time | hh:mm:ss | Time | 8 | 28 |
| | Battery Voltage | v | 0 - 99.9 | Scaled | 5 | 34 |
| | Array Type | - | ex:"INL" | Character | 3 | 38 |
| | Relative Humidity | % | 0 - 100 | Float | 7 | 45 |
| | Temperature | deg C | -90 - 200 | Float | 6 | 51 |
| Line 3 | Operator | - | ex:"JOHN" | Character | 9 | 14 |
| | Tx ID | - | ex:"ONE" | Character | 5 | 26 |
| | A-Spacing | m/ft | positive | Scaled | 6 | 38 |
| | Length Unit | - | M or FT | Character | 2 | 41 |
| | Ax (Grd or Sch Arrays) | # | in m or ft | Scaled | 8 | 48 |
| | Bx (Grd or Sch Arrays) | # | in m or ft | Scaled | 8 | 60 |
| | MAV telluric filter | | Enabled or Disabled | | | |
| Line 4 | Job Number | # | ex:"GOLD" | Character | 5 | 9 |
| | Line | # | ex:"1+00" | Character | 8 | 23 |
| | Line Direction | - | ex:"N" | Character | 2 | 25 |
| | Spread | # | ex:"A" | Character | 2 | 36 |

Line 5+ hardware inventory information, one line for each channel.

GDP-32 CR Data Block Sample

5715

CR 0837 2008-03-12 11:24:04 12.2v D-D 22.6% 35.0 DegC

Tx 2700 Rx 1500 N 60, 5

.125 Hz 16 Cyc Tx Curr 5.8

| | | | | | | | | | |
|---|----|---|---------|-------|-------|------|-------|-------|-------|
| 1 | Ex | 3 | 4.7325m | -13.3 | 36.24 | 0060 | 2.19 | 12.22 | 1.26K |
| 2 | Ex | 4 | 4.0778m | -10.4 | 62.45 | 0060 | 4.07 | 6.59 | 1.65K |
| 3 | Ex | 5 | 2.1836m | -9.0 | 58.52 | 0260 | 6.72 | 17.99 | 1.56K |
| 4 | Ex | 6 | 1.3414m | -12.3 | 57.52 | 0360 | 9.09 | 10.71 | 1.50K |
| 5 | Ex | 7 | 925.28u | -14.0 | 59.52 | 0360 | 9.76 | 1.92 | 1.97K |
| 6 | Ex | 8 | 898.44u | -16.2 | 82.56 | 0360 | 11.34 | -5.08 | 1.66K |

| Harmonics | | 1 | 3 | 5 | 7 | 9 | | | |
|-----------|---------|-------|---------|-------|---------|-------|---------|-------|---------|
| 1 | 4.7325m | -16.6 | 4.6972m | -26.5 | 4.6810m | -41.0 | 4.6529m | -47.8 | 4.6346m |
| 2 | 4.0778m | -4.6 | 4.0404m | 8.5 | 4.0270m | 23.6 | 4.0024m | 38.1 | 3.9899m |
| 3 | 2.1836m | -19.7 | 2.1641m | -36.5 | 2.1454m | -47.5 | 2.1421m | -68.0 | 2.1249m |
| 4 | 1.3414m | -22.2 | 1.3283m | -40.6 | 1.3224m | -56.9 | 1.3132m | -73.0 | 1.3002m |
| 5 | 925.28u | -23.7 | 913.52u | -40.9 | 907.61u | -55.6 | 893.09u | -85.1 | 879.39u |
| 6 | 898.44u | -26.9 | 887.21u | -40.9 | 866.87u | -45.3 | 883.42u | -82.5 | 881.35u |

GDP-32 CR data block structure

-- FIELD_NAME ----- UNITS -- RANGE --- TYPE ----- WIDTH -- END --

Line 1

| | | | | | |
|--------------|---|----------|---------|---|---|
| Block Number | # | 0 - 9999 | Integer | 4 | 4 |
|--------------|---|----------|---------|---|---|

Line 2

| | | | | | |
|-------------------|-------|------------|-----------|----|----|
| Survey Type | - | ex:"CR " | Character | 4 | 4 |
| Version Number | # | 0 - 9999 | Integer | 4 | 8 |
| Skip Flag | - | x or space | Character | 1 | 9 |
| Date | date | yyyy-mm-dd | Date | 10 | 19 |
| Time | time | hh:mm:ss | Time | 8 | 28 |
| Battery Voltage | volts | 0 - 13.0 | Float | 6 | 34 |
| Array Type | - | ex:"D-D" | Character | 3 | 38 |
| Relative Humidity | % | 0 - 100 | Float | 7 | 45 |
| Temperature | deg C | -90 - 200 | Float | 6 | 51 |

Line 3

| | | | | | |
|--------------|---|------------|-----------|---|----|
| Tx value | # | ±0-9999999 | Scaled | 8 | 11 |
| Rx value | # | ±0-9999999 | Scaled | 8 | 23 |
| Notch Filter | - | ex:"60, 5" | Character | 5 | 31 |

Line 4

| | | | | | |
|----------------|------|-----------|---------|---|----|
| Frequency | Hz | ex:0.125 | Scaled | 4 | 4 |
| # Cycles/Stack | # | 1 - 16384 | Integer | 5 | 14 |
| Tx Current | amps | 0 - 99999 | Scaled | 6 | 32 |

GDP-32 CR data block structure (continued)

-- FIELD_NAME ----- UNITS -- RANGE --- TYPE ----- WIDTH -- END --

Line 5: repeated for each channel measured.

| | | | | | |
|------------------------------------|------|------------|--------------|---|----|
| Channel Number | # | 1 - 16 | Integer | 1 | 2 |
| Skip Flag | - | sp,x,-,b | Character | 1 | 3 |
| Channel Type | - | ex:"Ex" | Character | 3 | 6 |
| N-Spacing | # | ±0 - 99999 | Scaled | 6 | 12 |
| 1 st Harmonic Magnitude | v | | Scaled w/exp | 8 | 21 |
| 3-point phase | mrad | | Scaled | 7 | 29 |
| Apparent Resistivity | Ωm | | Scaled w/exp | 7 | 37 |
| Gains/Attenuator | ###A | ex:"0060" | Character | 4 | 42 |
| Phase SEM | mrad | | Scaled w/exp | 6 | 49 |
| Self Potential | mv | | Scaled | 7 | 57 |
| Contact Resistance | Ω | | Scaled w/exp | 6 | 64 |

CR harmonic data lines

| | | | | | |
|----------------|----|---------|--------------|---|----|
| Channel Number | # | 1 - 8 | Integer | 2 | 2 |
| Magnitude 1 | v | | Scaled w/exp | 8 | 10 |
| Phase 1 | mr | ±6283.2 | Float | 7 | 18 |
| Magnitude 3 | v | | Scaled w/exp | 8 | 27 |
| Phase 3 | mr | ±6283.2 | Float | 7 | 35 |
| Magnitude 5 | v | | Scaled w/exp | 8 | 44 |
| Phase 5 | mr | ±6283.2 | Float | 7 | 52 |
| Magnitude 7 | v | | Scaled w/exp | 8 | 61 |
| Phase 7 | mr | ±6283.2 | Float | 7 | 69 |
| Magnitude 9 | v | | Scaled w/exp | 8 | 78 |
| Phase 9 | mr | ±6283.2 | Float | 7 | 86 |

NOTE: Extremely large values will shift data in the columns that follow.

A data block may be skipped by putting an "x" just to the right of the GDP program name, i.e. change:

CR 0837 2008-03-12 11:24:04 12.2v D-D 22.6% 35.0 DegC

to

CR x0837 2008-03-12 11:24:04 12.2v D-D 22.6% 35.0 DegC

Individual channels may be skipped by putting an "x" right after the channel number, i.e. change

2 4.0778m -4.6 4.0404m 8.5 4.0270m 23.6 4.0024m 38.1 3.9899m

to

2 x4.0778m -4.6 4.0404m 8.5 4.0270m 23.6 4.0024m 38.1 3.9899m

The polarity of individual channels can be flipped by putting a "-" after the channel number, i.e. change

2 4.0778m -4.6 4.0404m 8.5 4.0270m 23.6 4.0024m 38.1 3.9899m

to

2 -4.0778m -4.6 4.0404m 8.5 4.0270m 23.6 4.0024m 38.1 3.9899m

Raw file survey configuration keywords

Hemavgw will read a limited set of survey configuration keywords from raw files, so that array conventions can be extended to more general configurations. Raw file keyword records are similar to \$keyword=values format used in mde, zdb and avg files. A leading \$ flags the text as a keyword record. The keyword is separated from its values by the = character. Multiple values are separated by commas. By default, raw file keyword variables are set to values consistent with standard GDP conventions. The standard conventions can be modified by inserting \$keywords records into the raw file just before the data blocks that are to be affected.

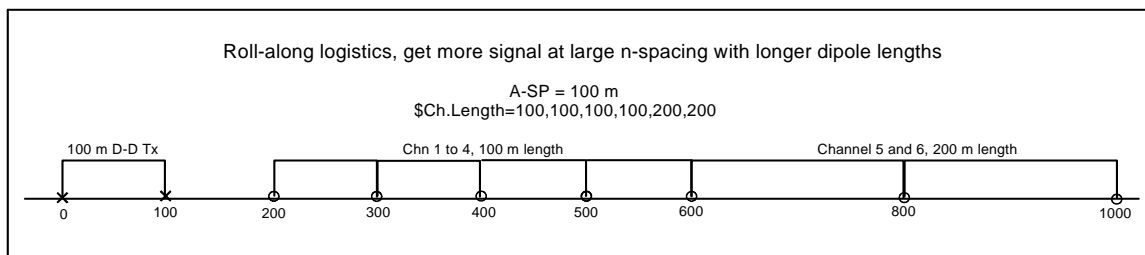
Variable Rx dipole lengths

The harmonic EM extension to conventional surveys is to allow multiple receiver dipole lengths in a single setup. **Hemavgw** uses A-SP, Tx, Rx and the lowest numbered n-spacing to calculate how station numbers scale to a unit dipole length in meters or feet. For dipole-dipole, the transmitter dipole is one A-SP long. The header block A-SP value in meters or feet is used as a unit dipole length to calculate both transmitter electrode station numbers and the lower numbered receiver electrode stations in combination with the n-spacing values specified for each GDP channel. Variable receiver dipole lengths specified by:

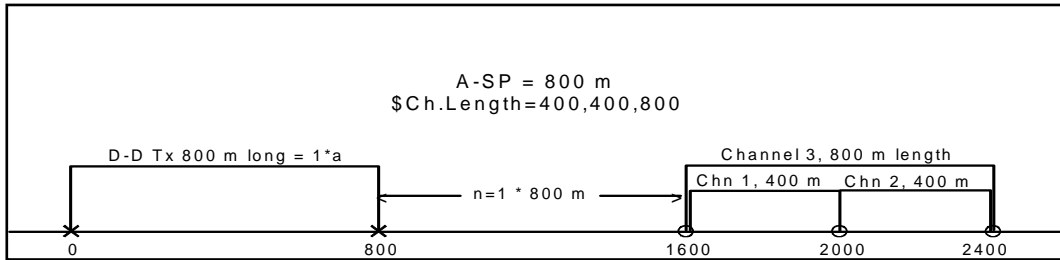
\$Ch.Length=length1, length2, ..., lengthN

can be used to relocate the higher number receiver electrodes. Length1, ..., lengthN must be in the same length units as the A-SP value in the preceding raw file header block.

Longer receiver dipole lengths can be used to increase signal strength at large n-spacings.



For a specific \$Ch.Length example with raw file text, consider the following configuration:



Example \$Ch.Length=400,400,800 raw file text

```
0009
CR 0843 2009-09-10 15:31:15 12.4v D-H 26.0% 41.7 DegC
OPER Mark R TX ID 2049 A-SP 800 M
JOB 998 LINE 1 N SPREAD 1 MAV Enabled
1 DiffAmp Notch 60,3-5,9 S/N 212 Passed 1.00000
2 DiffAmp Notch 60,3-5,9 S/N 167 Passed 1.00000
3 DiffAmp Notch 60,3-5,9 S/N 164 Passed 1.00000
4 DiffAmp Notch 60,3-5,9 S/N 248 Passed 1.00000
5 DiffAmp Notch 60,3-5,9 S/N 359 Passed 1.00000
6 DiffAmp Notch 60,3-5,9 S/N 466 Passed 1.00000
Front Panel S/N 12, Cal S/N 38, Temp 41.7, Humidity 26.0, EPROM 030901BLD321
```

\$Ch.Length=400,400,800

```
0010
CR 0843 2009-09-10 15:44:42 12.3v D-H 26.7% 41.7 DegC
Tx 0 Rx 1600 N 60, 5
.125 Hz 16 Cyc Tx Curr 10
1 Ex 1 5.4366m 0.1 0350 0.30 11.95 50.3K
2 Ex 1.5 6.2987m -0.6 0540 0.26 9.75 50.4K
3 Ex 1 6.8841m -2.3 0630 0.30 -6.59 50.8K
Harmonics 1 3 5 7 9
1 5.4366m 78.4 5.5818m 227.0 5.8439m 364.8 6.2299m 486.8 6.7041m 592.7
2 6.2987m 31.3 6.3343m 94.0 6.3983m 155.4 6.5045m 215.1 6.6316m 273.0
3 6.8841m 17.3 6.9025m 54.9 6.9312m 90.6 6.9908m 126.3 7.0586m 161.3
```

\$Ch.Length=400,400,800 is inserted just after a header block specifying an A-SP = 800 meters and just before a D-D data block with three active channels, channels 1 and 2 each 400 m long and channel 3 spanning 800 m. **Hemavgw** depends upon the blank line separators between each raw file header and data block to mark the beginning and end of each block, so a blank line is left just above \$Ch.Length=400,400,800.

GDP-32 FLD Files: .raw reformatted by program SHRED or SHREDCNSL

The legacy programs Shred or ShredCnsl flatten block oriented GDP raw files into a tabular spreadsheet format with space-separated column-oriented values.

HEADER Record Structure

| -- FIELD_NAME | ----- UNITS | -- RANGE | --- | TYPE | ----- | WIDTH | -- | END | -- |
|-----------------------|-------------|-----------|-----|--------------|-------|-------|----|-----|----|
| Record Type | - | H , D | | Character | | 1 | | 1 | |
| Skip/Average Flag | # | 0 , 1 | | Integer | | 1 | | 3 | |
| Block Number | # | 0 - 9999 | | Integer | | 4 | | 8 | |
| Header Label | # | 0 - 999 | | Integer | | 3 | | 12 | |
| Sequence Number | # | 0 - 9 | | Integer | | 1 | | 14 | |
| Survey Type, Version | - | | | Character | | 8 | | 23 | |
| Date | date | dd mmm yy | | Date | | 8 | | 32 | |
| Time | time | hh:mm:ss | | Time | | 8 | | 41 | |
| Voltage | v | 0 - 99.9 | | Scaled | | 4 | | 46 | |
| Array Type | - | ex:"D-D" | | Character | | 3 | | 50 | |
| Operator | - | ex:"JOHN" | | Character | | 9 | | 60 | |
| Tx Identification | - | ex:"ONE" | | Character | | 4 | | 65 | |
| A-Spacing | m | positive | | Scaled | | 6 | | 72 | |
| Job Number | - | ex:"GOLD" | | Character | | 5 | | 78 | |
| Line Number | - | ex:"1+00" | | Character | | 8 | | 87 | |
| Line Direction | - | ex:"NE" | | Character | | 2 | | 90 | |
| Spread | - | ex:"A" | | Character | | 2 | | 93 | |
| Tx Shunt (CR or RPIP) | Ω | positive | | Scaled w/exp | | 9 | | 103 | |

For Grd (gradient) or Sch (Schlumberger) arrays:

| | | | | | | | | | |
|----|--------------|---|-----------------|--------|--|---|--|-----|--|
| Ax | (Sch or Grd) | m | $\pm 0-9999999$ | Scaled | | 8 | | 112 | |
| Bx | (Sch or Grd) | m | $\pm 0-9999999$ | Scaled | | 8 | | 121 | |

CR Data Record Structure

| FIELD_NAME | UNITS | RANGE | TYPE | WIDTH | END |
|-------------------|-------|------------|--------------|-------|-----|
| Record Type | - | H , D | Character | 1 | 1 |
| Skip/Average Flag | # | 0 , 1 | Integer | 1 | 3 |
| Block Number | # | 0 - 9999 | Integer | 4 | 8 |
| Header Label | # | 0 - 999 | Integer | 3 | 12 |
| Sequence Number | # | 0 - 9 | Integer | 1 | 14 |
| Date | date | dd mmm yy | Character | 8 | 23 |
| Time | time | hh:mm:ss | Character | 8 | 32 |
| Voltage | v | 0 - 99.9 | Scaled | 4 | 37 |
| Frequency | Hz | ex:" 8" | Scaled | 5 | 43 |
| Cycles | # | 1 - 16384 | Integer | 5 | 49 |
| Tx Current | amps | 0 - 99999 | Scaled w/exp | 8 | 58 |
| Tx | # | ±0-9999999 | Integer | 8 | 67 |
| Rx Calculated | # | pos or neg | Scaled w/exp | 11 | 79 |

Secondary structure

| | | | | | |
|--------------------|------|------------|--------------|----|-----|
| Channel Type | - | ex:"Ex" | Character | 3 | 83 |
| Polarity Flip Flag | # | 0 - 1 | Integer | 1 | 85 |
| N-Spacing | # | ±0-9999999 | Scaled | 8 | 94 |
| Magnitude | v | | Scaled w/exp | 10 | 105 |
| 3-Point DC Phase | mr | ±6283.2 | Scaled w/exp | 10 | 116 |
| Resistivity | Ωm | | Scaled w/exp | 10 | 127 |
| Gains/Attenuator | ###A | ex:"0260" | Character | 4 | 132 |
| SEM | mr | | Scaled | 7 | 140 |
| Self Potential | mv | | Scaled | 7 | 151 |
| Contact Resistance | Ω | | Scaled w/exp | 9 | 161 |
| External Amp Gain | # | 1-999999 | Integer | 6 | 167 |

Harmonic data structure

| | | | | | |
|-------------|----|---------|--------------|----|-----|
| Magnitude 1 | v | | Scaled w/exp | 10 | 178 |
| Phase 1 | mr | ±6283.2 | Float | 7 | 186 |
| Magnitude 3 | v | | Scaled w/exp | 10 | 197 |
| Phase 3 | mr | ±6283.2 | Float | 7 | 205 |
| Magnitude 5 | v | | Scaled w/exp | 10 | 216 |
| Phase 5 | mr | ±6283.2 | Float | 7 | 224 |
| Magnitude 7 | v | | Scaled w/exp | 10 | 235 |
| Phase 7 | mr | ±6283.2 | Float | 7 | 243 |
| Magnitude 9 | v | | Scaled w/exp | 10 | 254 |
| Phase 9 | mr | ±6283.2 | Float | 7 | 262 |

Reference channel magnitude (only when Reference channel in use)

| | | | | | |
|---------------------|---|--|--------------|----|-----|
| Reference Magnitude | v | | Scaled w/exp | 10 | 273 |
|---------------------|---|--|--------------|----|-----|

Laboratory Rock value structure (Array Type: LAB)

| | | | | | |
|---------------------|-----------------|--|--------------|---|-----|
| Tx Shunt Resistance | Ω | | Scaled w/exp | 9 | 283 |
| Rock Sample Length | cm | | Scaled w/exp | 9 | 293 |
| Rock Sample Area | cm ² | | Scaled w/exp | 9 | 303 |

HEMAVGW **zdb** and **avg** files: Harmonic EM data

zdb and **avg** files have the same format, but **zdb** files are used to store data with unaveraged repeats, while the file name extension **avg** implies that repeat measurements have been averaged. **zdb** files keep track of the detailed skip-flag pattern set during interactive QC of unaveraged data. **Hemavgw** can re-read data from **zdb** files to revisit QC decisions without starting over from the beginning.

avg files may have comment lines preceded by a leading “\”, “/”, “!” or “#” anywhere within the file, although they are normally grouped at the top of the file.

Keyword records with a leading “\$” character are also present and play a large role in recording information that does not fit into a tabular spreadsheet format. Keyword records have a `$program:group.variable=value(s)` format. The program name is optional, but if present the keyword record is ignored if the program name is not **hemavgw**. Version 2 keywords generally have a `group.variable` structure with the group name unifying keywords with a common theme. An equals “=” sign separates the keyword from one or more comma-separated values. String values which may include commas as part of the value, instead of as a field separator, should be enclosed in quotes. To allow future file-format extension, programs should skip unrecognized keywords without generating an error.

Records with a leading letter are interpreted to contain column labels. At least one line holding column labels must precede numerical data. Column label matching is case insensitive, but does not allow substring matching. Column order is not fixed and all possible columns may not be present in a particular file. If an essential column is missing, the program will show a warning message and abort input.

Numeric data records begin with a leading number. Numerical values are free format with columns separated by either spaces or commas, although comma separated values are preferred. Missing numeric values are flagged by a “*” symbol or empty space bracketed by commas.

Hemavgw *.avg-file keywords:

Survey annotation

| | | |
|------------|---------------------------|------------------------|
| Job.Name | = project name | (128 character string) |
| Job.Area | = project area | (128 character string) |
| Job.For | = customer company name | (128 character string) |
| Job.By | = contractor company name | (128 character string) |
| Job.Number | = job label or number | (16 character string) |
| Job.Date | = data acquisition date | (16 character string) |

Survey configuration

| | |
|------------------|---|
| Survey.Array | = array type (for IP: D-D, P-D, P-P, Grd, Sch, D-H, Lab) |
| Line.Name | = line label (16 character string) (alias = JobLine) |
| Line.Number | = line number across-line coordinate (float) |
| Line.Azimuth | = line azimuth in direction of increasing stn # (float, deg E of N) (alias = BrgLine) |
| Stn.GdpBeg | = first GDP station number (float) (alias = StnBeg) |
| Stn.GdpInc | = GDP station number increment (non-zero float) (alias = StnDelt) |
| Stn.GdpUnitScale | = gdp stn number scale (m/GdpStn#) |
| Stn.Beg | = possibly rescaled first station number (float) (alias = LblFrst) |
| Stn.Inc | = possibly rescaled station number increment (float) (alias = LblDelt) |
| Stn.UnitScale | = client station number scale (m/Stn#) |
| Stn.Left | = rescaled station number on left edge of pseudosection plot (float) (alias=LblFrst) |
| Stn.Right | = rescaled station number on right edge of pseudosection plot (float) |
| Rx.Area | = Rx magnetic field antenna effective area or rock sample area (m ²) |
| Rx.Length | = Rx dipole length (m) |
| Rx.HPR | = Rx x-component heading & pitch, z component roll (degrees) |

Units

| | | |
|-------------|------------------------|----------------------------|
| Unit.Length | = length units | (m,ft) (alias = Units) |
| Unit.Time | = time units | (usec,msec,sec) |
| Unit.V | = voltage units | (uV/A,mV/A,V/A, uV,mV,V) |
| Unit.B | = magnetic field units | (pT/A,nT/A,uT/A, pT,nT,uT) |

HEMAVGW processing control parameters

| | |
|------------------------|--|
| HEMAVGW:Process.TS | = yes = process cac file time series |
| HEMAVGW:Process.STACK | = yes = process cac file stacks |
| HEMAVGW:Process.DECAY | = yes = process cac file decays |
| HEMAVGW:Process.BINNED | = yes = process binned data |
| HEMAVGW:Stack.Type | = stack type, {Straight, Taper, Robust} |
| HEMAVGW:Stack.Taper | = stack taper {0 to 6} |
| HEMAVGW:Stack.Trim | = stack trim (alpha trimmed mean %) |
| HEMAVGW:Avg.Type | = averaging method {Straight,Robust} |
| HEMAVGW:Phase.Flip | = yes = phase sign flipped to IP convention |
| HEMAVGW:3Pnt.Type | = 3-point extrapolation data {Real & Imag, Mag & Phase} |
| HEMAVGW:3Pnt.Coeff | = 3-point coefficients {Quadratic,Coggon 1.5,Coggon 2.5,Custom Freq} |
| HEMAVGW:3Pnt.Freq | = 3-point frequencies (hertz) |
| HEMAVGW:3Pnt.Wgt | = 3-point data weights |
| HEMAVGW:TxFreq.Min | = minimum Tx frequency to use (hertz) |
| HEMAVGW:TxFreq.Max | = maximum Tx frequency to use (hertz) |
| HEMAVGW:MHAFreq | = maximum harmonic frequency, enumeration index {1=1,2=3,3=5,4=7,5=9} |
| HEMAVGW:Ch.NumberType | = channel number useage (stn #,stn # offset, n-spacing, n-offset, antenna #) |

HEMAVGW pseudosection color-fill limits

| | |
|----------------|--|
| HEMAVGW:VMdat | = minimum and maximum E-field magnitude (mV/A) |
| HEMAVGW:VPdat | = minimum and maximum E-field phase (mrad) |
| HEMAVGW:VRdat | = minimum and maximum real(E-field) (mV/A) |
| HEMAVGW:VI dat | = minimum and maximum imag(E-field) (mV/A) |
| HEMAVGW:VMerr | = minimum and maximum E-field magnitude error (%) |
| HEMAVGW:VPerr | = minimum and maximum E-field phase error (mrad) |
| HEMAVGW:VRerr | = minimum and maximum real(E-field) error (mV/A) |
| HEMAVGW:VIerr | = minimum and maximum imag(magnetic field) error (mV/A) |
| HEMAVGW:BMdat | = minimum and maximum magnetic field magnitude (nT/A) |
| HEMAVGW:BPdat | = minimum and maximum magnetic field phase (mrad) |
| HEMAVGW:BRdat | = minimum and maximum real(magnetic field) (nT/A) |
| HEMAVGW:BI dat | = minimum and maximum imag(magnetic field) (nT/A) |
| HEMAVGW:BMerr | = minimum and maximum magnetic field magnitude error (%) |
| HEMAVGW:BPerr | = minimum and maximum magnetic field phase error (mrad) |
| HEMAVGW:BRerr | = minimum and maximum real(magnetic field) error (nT/A) |
| HEMAVGW:BIerr | = minimum and maximum imag(magnetic field) error (nT/A) |

HEMAVGW *.avg-file columns:

| | |
|-----------|--|
| Tx.GdpStn | = Tx GDP station number, used as Tx ID for D-H array key to TWC file |
| Rx.GdpStn | = Rx GDP station number |
| Plt.X | = Pseudosection along-line plot point (stn #) |
| Plt.Z | = Pseudosection plot point depth (stn #) |
| Plt.Nsp | = n-spacing (when applicable) |
| Plt.East | = Plot point easting (length units) |
| Plt.North | = Plot point northing (length units) |
| Plt.Elev | = Plot point elevation (length units) |
| Tx.Amp | = transmitter current (frequency-domain amps) |
| Tx.Phz | = transmitter phase (mrad) |
| Tx.NCycle | = number of cycles per stack |
| Tx.Freq | = transmitter repetition rate (hertz) |
| Rx.Freq | = receiver harmonic frequency (hertz) |
| Rx.Cmp | = EM component (should be Ex or Ey for CR) |
| Rx.CntRes | = Rx dipole contact resistance (ohms) |
| VA.mag | = V/A magnitude (V/A or uT/A) |
| VA.phz | = V/A phase (mrad) |
| VA.real | = real(V/A) (V/A or uT/A) |
| VA.imag | = imag(V/A) (V/A or uT/A) |
| VA.%err | = V/A magnitude error (%) |
| VA.perr | = IP phase error (msec) |
| VA.wgt | = V/A weight (0=skip, otherwise use) |
| SP.mag | = self-potential (mV) |
| SP.err | = self-potential error (mV) |
| Gdp.Blk | = GDP-32 data block number |
| Gdp.Chn | = GDP-32 analog channel number |
| Gdp.Date | = Data acquisition date |
| Gdp.Time | = Data acquisition time of day |
| Gdp.Gain | = GDP gain stages as log2 values and the attenuator out or in |