

PEICOMP PROGRAM

**Program for calculation of the coefficients used for
magnetic compensation.**

User Manual

Revision 5.1.10



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1 PEICOMP - GENERAL:

This program was designed to calculate set of coefficients that is used for magnetic compensation. Magnetic compensation is performed by PEIView program using calculated coefficients.

1.1 REQUIREMENT FOR MAGNETIC COMPENSATION

Modern magnetometers and signal processing boards for magnetic measurements now enable both high sensitivity and high sampling rates to be coupled with a broad bandwidth. The magnetic interference from the airframe or even the sensor itself due to attitude changes are far greater than the inherent resolution of the system. Changing of magnetic parts and the use of coils and permalloy strips can only partially remove the interference effects. Proper magnetic compensation, either in real time or post processing is necessary to remove the aircraft's interference. The compensation must address all of the interference sources. Magnetic compensation is now the limiting factor in the overall useful sensitivity of airborne magnetic surveys.

It has been our philosophy to use very much a graphical approach to magnetic compensation so that the operators can always see down to the noise levels of the system. By this technique interference effects can often be seen immediately and cured before expensive airtime is wasted.

Additionally we recommend the use of wide bandwidth, which must be matched for the magnetometer and the compensating fluxgate. We recommend the use of 10 Hz sampling with a 2 Hz bandwidth to reduce the effects of aliasing.

The **Pico Envirotec** method uses purely software techniques, without the use of varying currents and coils which can distort the field around the sensor. The **Pico Envirotec** method records the compensated data and all of the required raw data necessary to re-compensate the magnetometer data in post processing.

1.2 SOURCES OF MAGNETIC INTERFERENCE

Magnetic interference in a geophysical aircraft environment comes from several sources. These include:

A) **Permanent magnetism**, mainly from engines and other 'hard iron' magnetic components close to the sensor. This interference is proportional to the coupling with the magnetic field.

B) **Induced magnetism**, from 'soft iron' components close to the sensor. This interference is proportional to the coupling with the magnetic field and the magnitude of the magnetic field and is a function of the susceptibility of these components.

C) **Eddy current terms**, from rate of change of movement of conductive surfaces in a magnetic field. This interference is proportional to the coupling with the magnetic field; its magnitude and the rate of change of altitude.

D) **Heading effects** of the magnetometer sensor itself.

E) **Altitude changes** in a vertical magnetic gradient.

F) Additional effects come from **moving surfaces** and materials, such as trim surfaces and push rods, and distortions of the airframe through flexing.

G) **Electrical and mechanical interference** in the pass band of the system.

The order of magnitude of these interference effects varies greatly from installation to installation. Typically permanent terms could bring 10 nT of magnetic interference, the induced terms 5 nT and eddy current terms 2 nT. The heading effects of modern magnetometers can be as much as 0.5 nT while the vertical magnetic gradient at 3000 m. above ground is of the order or 30 pT/m or 10 pT/ft.

On a fairly clean magnetic installation moving surface and electrical and mechanical interference should be better than 1 nT. These can be tested on the ground in a quiet location with the sensor held in a rigid position. As these interference sources are not measured they will affect the residual compensation and should be minimised. In fact the cleaner the installation, with respect to these unmeasured interference effects, the poorer is the overall improvement by this compensation.

The main differences in these terms can be seen in their magnitude and phase relative to a sinusoidal motion.

The permanent interference effect would be in phase with this motion.

The induced component is again in phase with the coupling but with only an increasing effect of the measured field, maximum along the north and south directions where coupling with the magnetic field is greatest.

The eddy current term has a magnitude proportional to the absolute value of the magnetic field coupling and to the rate of change of coupling.

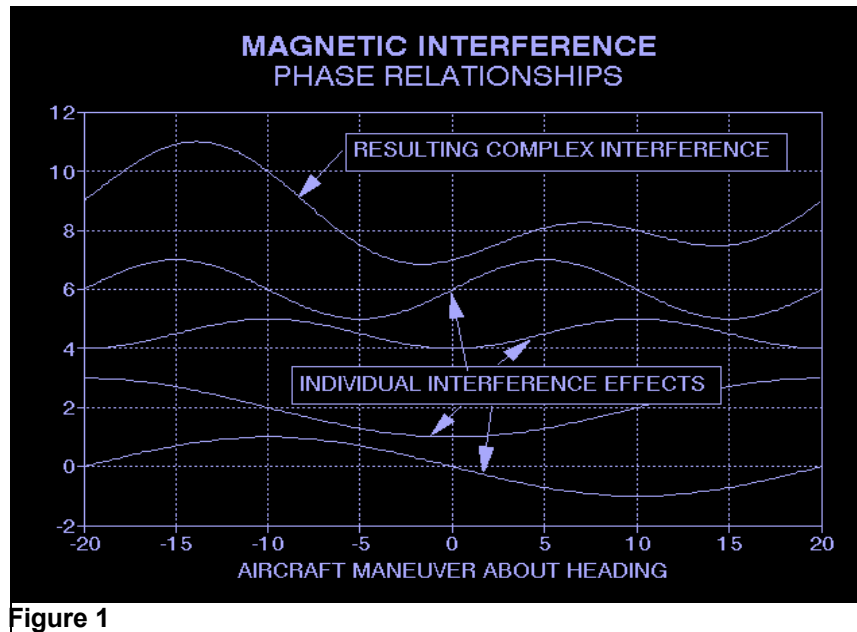


Figure 1

Above we show individual interference effects for a sinusoidal motion. They can be at the frequency of the motion, both in phase and 90 degree phase shifted. They can also have a frequency twice that of the motion, again in or 90 degree phase shifted. The resulting magnetic interference is the vector sum. This can have a complex shape, depending on the magnitudes of the interference.

1.3 REALITY IN COMPENSATING A REAL AIRCRAFT

The residual magnetic interference is somewhat more complex than a simple sine wave manoeuvre. In reality the magnetic interference is in three dimensions, longitudinal, transverse and vertical. Additionally the components in each dimension have different interference effects from pitch, roll and yaw motions. Similar phase shifted responses exist for the for rolls and pitches. The summed interference is much more complex as the three dimensional attitude and rate of change of attitude of a real aircraft is inter-related.

In a real environment the aircraft is also moving through a changing magnetic field. Even high above ground level there still exists long wavelength gradients and curvature in the magnetic field. By carrying out a box manoeuvre the background magnetic gradient changes at the same time as the heading effect of the aircraft. This makes it extremely difficult to separate the two effects.

1.4 BASES OF COMPENSATION

The basis of our compensation is the reduction of motion induced noise on the selected magnetic elements. These can be individual sensor or various gradient

configurations. This motion noise comes from the complex three-dimensional magnetic signature of the airframe as it changes attitude with respect to the magnetic field vector. The noise comes from permanent, induced and eddy effects of the airframe plus additional heading effects of the individual Cs sensors.

Due to the background magnetic changes experienced in real flying conditions, long wavelength geological interference, it is felt that it is not easy to obtain adequate compensation coefficients, which can be used on all survey headings. Only in extremely low gradient areas would this technique give reasonable results. This is due to the fact that these background changes alter with the heading and have the same high frequency components. They are, therefore, indistinguishable from heading effects due to the airframe alone. Attempts to use 1 set of coefficients for all headings average these background errors into the compensation coefficients and produce inferior results during compensation.

Our approach has been to use four individual sets of coefficients, one each for the four cardinal headings. These are assigned to be nominally 'N', 'S', 'E' and 'W'. On survey the changes from the nominal line are small, typically within ± 20 degrees for pitch, roll and yaw.

We define 4 cardinal headings for each survey, even if only 2 are used. These cardinal headings are normally, but not necessarily, orthogonal. The Main Cardinal Heading is defined as the grid value of the cardinal heading closest to grid north. For example, the main survey direction is on a heading of 100 degrees east of grid north then the cardinal headings are 10, 100, 190 and 280 degrees with the Main Cardinal Heading 10. We then define our 10-degree east heading as 'NORTH'. Similarly the 100-degree heading is defined 'EAST', the 190 deg heading as 'SOUTH' and the 280 degree heading as 'WEST'. This convention will be carried through from the SURVEY program to post-processing.

The magnetic compensation is carried out in software without the use of active distorting magnetic fields. A magnetic interference model has been constructed with three orthogonal sets of components. This assumes a magnetically rigid magnetic interference model.

A three-axis fluxgate is used to measure the coupling of the three axes with the background magnetic field. This sensor is very sensitive to attitude changes and is used to accurately monitor the aircraft reference frame. The frequency response and sample rate of the **PEI** Analog Processor card used to measure the fluxgate signals is the same as that of the **PEI** Magnetometer Processor card. This means that there is no phase distortion of these synchronised measurements. This leads to improved compensation throughout the pass band of the system.

A series of pitch, roll and yaw motions are carried out on each survey direction to vary this coupling and gather fluxgate, barometric and measured magnetic field data. This data is processed using a ridge regression technique to find a stable set of coefficients for

the model. When the compensation algorithm is run using the model and coefficients, either in real-time or post-processing, a magnetically compensated data set is generated.

We have tried to make this software as production orientated as possible, to supply the operator with real-time compensated data to view, confirming that it meets company specifications, and continue flying.

The programs supplied should enable the user to achieve software magnetic compensation for total field data. This can be carried out in real-time using previously calculated compensation coefficients or in post-processing using a selection of compensation coefficients.

1.5 STAGES OF COMPENSATION

The compensation takes four stages:

- A) Acquisition of motion test data.
- B) Reduction of this data to produce compensation coefficients.
- C) Production use of these coefficients in real time to supply compensated magnetic elements.
- D) Post processing, if desired, of the raw data with other sets of compensation coefficients for improved results, if valid.

1.6 ACQUISITION WITH AGIS / IRIS

The acquisition of motion test data should take approximately 20 minutes. Let us consider that we want to fly N-S traverses and E-W tie lines. The test should consist of the following:-

1) Have all equipment in normal operating conditions. The sample rate should be that of the survey. 10 Hz sampling with a 2 Hz bandwidth is recommended for all surveys. All the equipment that would normally be "ON" during a survey flight should on. If the aircraft is equipped with an auto-pilot it should be turned off and the aircraft flown manually. Aircraft systems that consume large amounts of power such as air conditioning should be either turned off and left off or placed in a mode where the compressor and fan systems are continually on and do not cycle. It should be noted that whatever aircraft systems are on during the compensation test flight must be "ON" for all surveys flights. Failure to observe this practice will result in poor compensation results during survey data acquisition.

2) The pilot(s) should be consulted to ensure they understand the following, often somewhat conflicting, ideal requirements.

The compensation test should be carried out in a magnetically quiet area at high altitude, away from ground effect, at least 8,000 feet above ground. The normal data acquisition program should be run with the sample rate the same as that to be used in the survey. During each of the four lines the aircraft should perform three each complete pitch, roll and yaw motions. These should be smooth and as symmetrical as is possible, of typically 5-10 second period.

The motions should be consistent with normal aircraft motion experienced during survey data acquisition. Roll manoeuvres should be +/-10 degrees peak to peak, pitch manoeuvres should be +/-5 degrees peak to peak and altitude changes should also be minimised, 50 m. or less if possible, and yaw manoeuvres should be +/- 5 degrees peak to peak. Only the aircraft surfaces that are used on line to alter the aircraft attitude should be used, e.g. do not use rudder excessively if this is not normally used as magnetic push rods may complicate the compensation. The order of motions is not critical. It is, however, good procedure and enables us to view the replot in a more meaningful way. The line should be closed, the aircraft set on a new heading, e.g. west, and the same motions carried out. The motions should then be carried out again on the remaining south and east headings. IN order to assist in data analysis the operator should note on the flight log the start and end fiducials for each of the 12 manoeuvres.

The operator should then have four separate data files named B???????.P??, if data is collected using an AGIS / IRIS data system. An example would be B6011909.p00, B6011909.p01 for data gathered on January 19, 2006 at 9 o'clock.

The reduction of the data to calculate the coefficients can be carried out on the aircraft but is easier to do it on the ground, either on the aircraft system or a similar PC computer. It is recommended that a plot is carried out of the data at the fastest sample rate to view the fluxgate and the magnetometer signals to ensure that there are no glitches or other problems with the data. The user should also select the fid (record) ranges to use for each heading. There should be from 800 to 2000 data samples for each line.

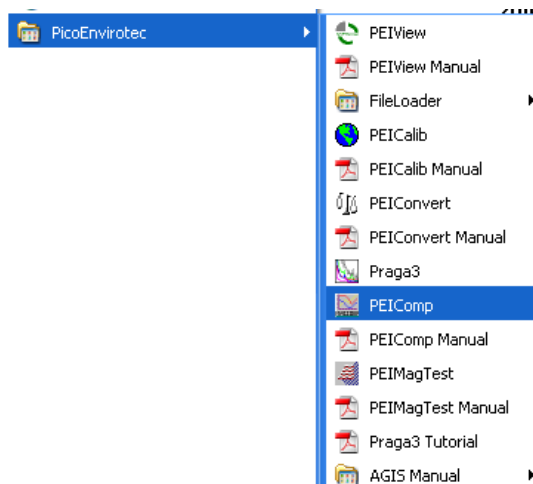
It is recommended that this test procedure should be carried out at the beginning of each survey and every two weeks or whenever any major magnetic component is changed.

2 PEICOMPENSATION - USE

2.1 INSTALL / SETUP THE PROGRAM

PEICompensation program is included into PEI Support Programs package and installed together with other PEI software. See Program Installation manual for more details.

After installation shortcut to PEICompensation application (PEIComp) is created on the computer desktop and in Start / All Programs menu:



2.2 WORKING WITH PEICOMP PROGRAM

2.2.1 Introduction

The compensation box flight data serves as source data for PeiComp program. During flight each heading data can be recorded in separate file or all four headings data recorded into one file.

If there is no data for all four orthogonal headings, compensation coefficients can be calculated for existing headings.

PEIComp program accepts files in PEI binary data format. If the source data saved as ASCII format file, there is provision to convert it to Pico Envirotec data format (see section 2.2.5).

When the file is loaded in PEIComp program, the user has to **specify magnetic and position data** needed for coefficients calculation: fluxgate magnetometer data channels (x, y, z), raw magnetometer data channel(s), altitude, X and Y position data. The X and Y coordinate are used for heading calculation.

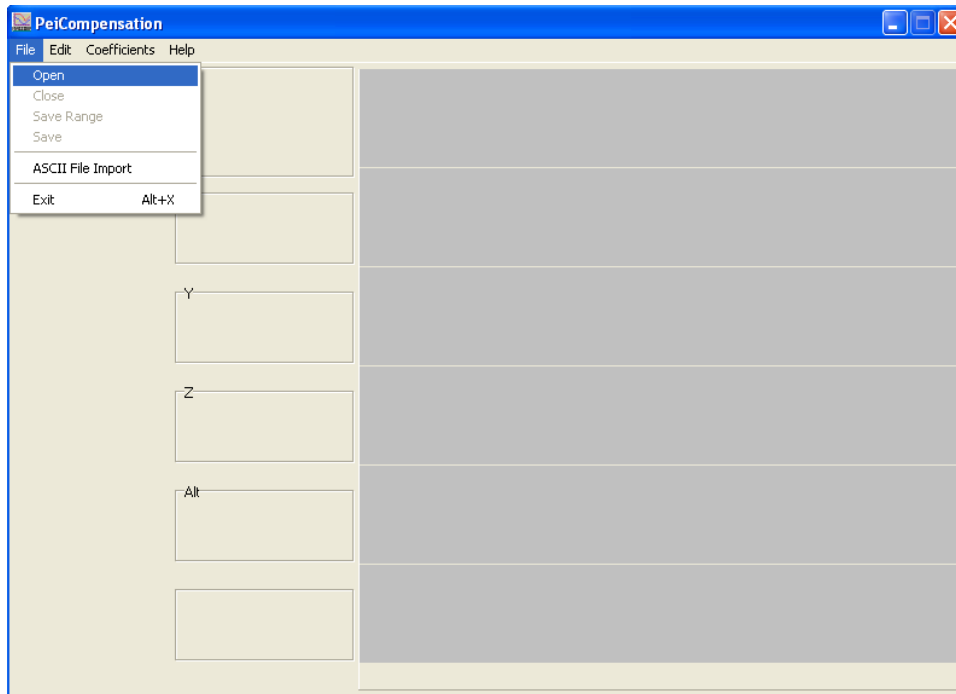
Then **select the proper data range of each heading** from the source file(s) and save it in a separate range file. If four headings data is present, four separate range files have to be created.

The next step is to **calculate coefficients of each heading** using range files as source data. The user can correct range file data before calculation.

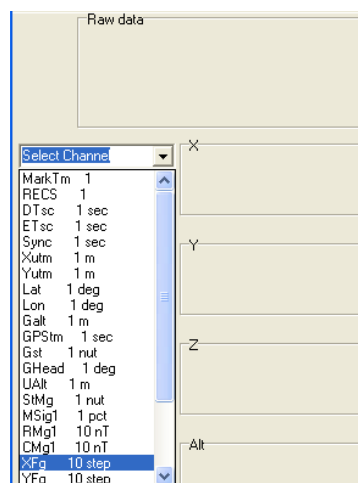
Finally, when all headings are processed, calculated **coefficients are saved** into the coefficient file.

2.2.2 Create Range File

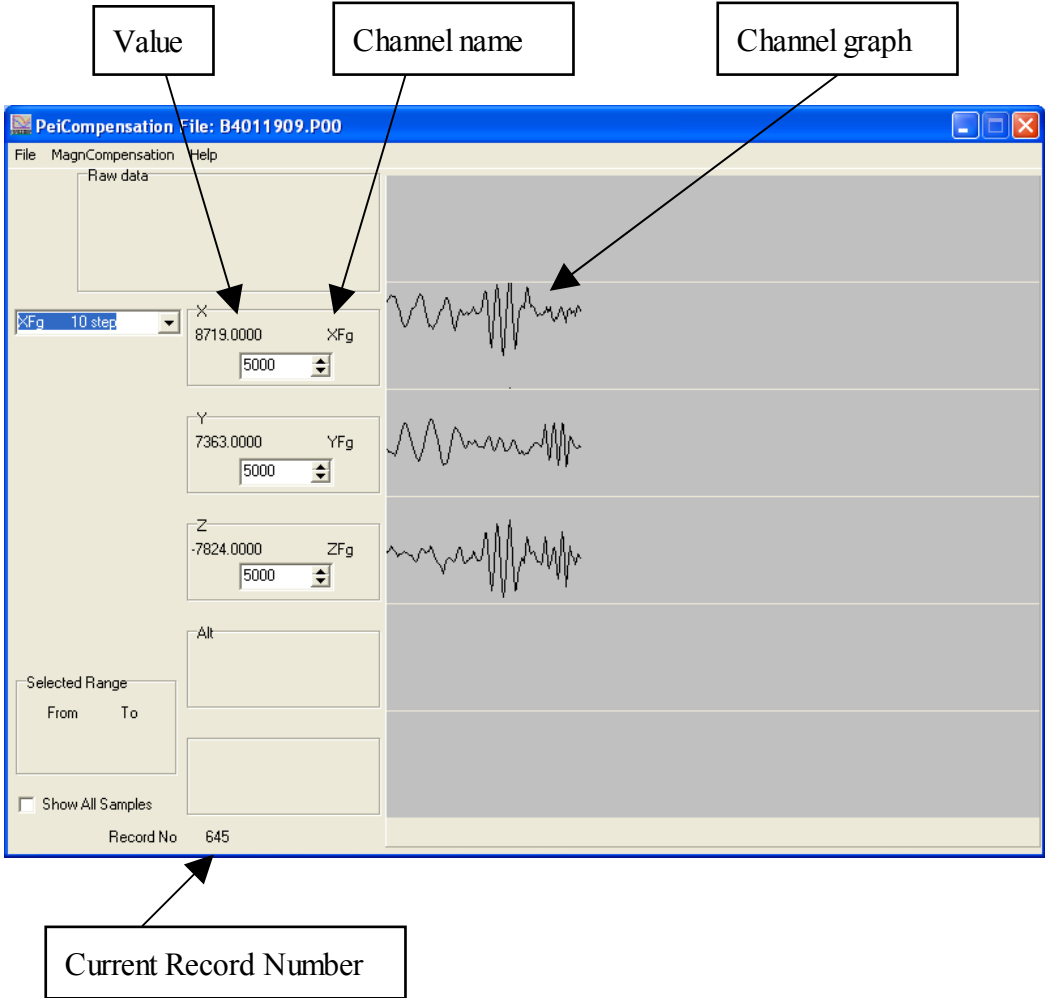
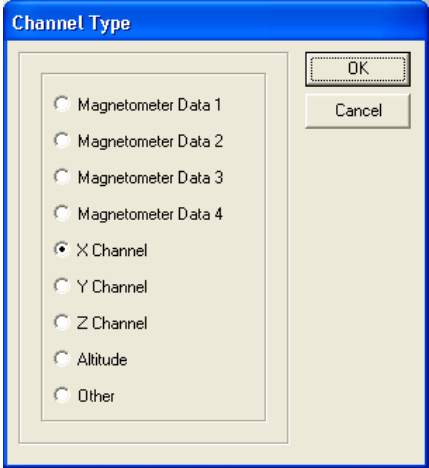
Once the program is started and goes through a “splash” screen the operator should open a file that contains necessary data channels for coefficients calculation.



All file channels are listed in Select Channel drop down list. Select the data required for the coefficients calculation. Start with X-fluxgate channel:



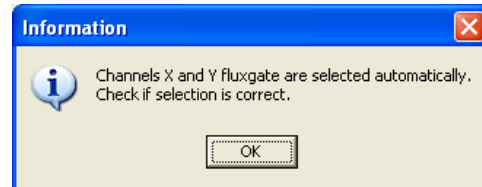
Once a channel is selected; the Channel Type options window will appear. The user has to indicate type of the channel. The selected channel data will be displayed on the corresponding chart. The user can adjust the scale.



Continue with all required channels:

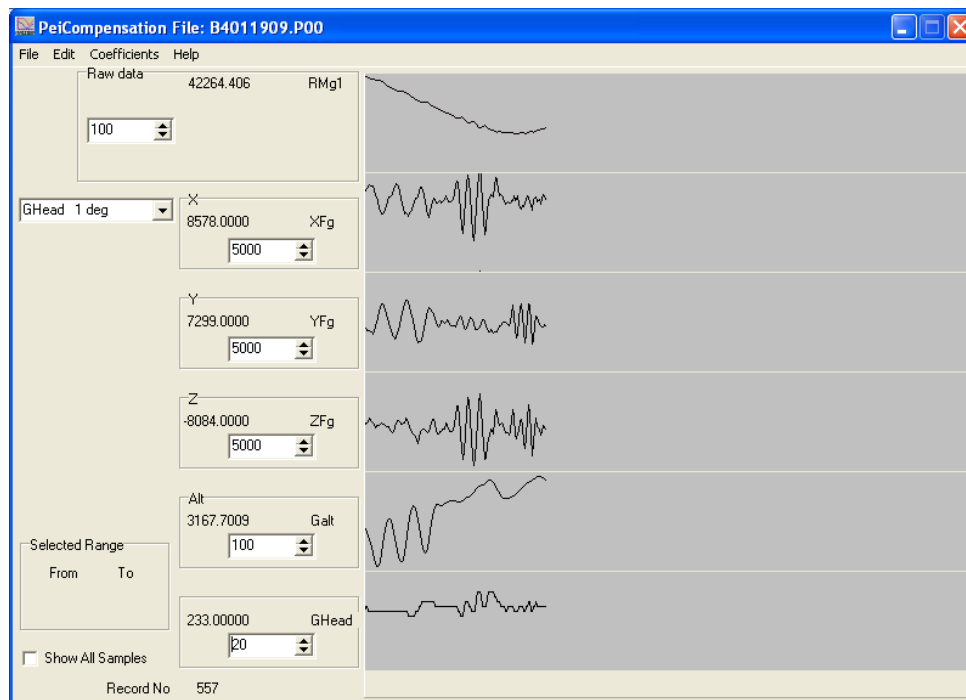
- X-fluxgate
- Y-fluxgate
- Z-fluxgate
- Raw magnetometer data (up to four channels)
- Altitude
- Record channel (optional)

Note: After X-fluxgate channel is selected, Y-fluxgate and Z-fluxgate channels are selected automatically. Information message will appear:

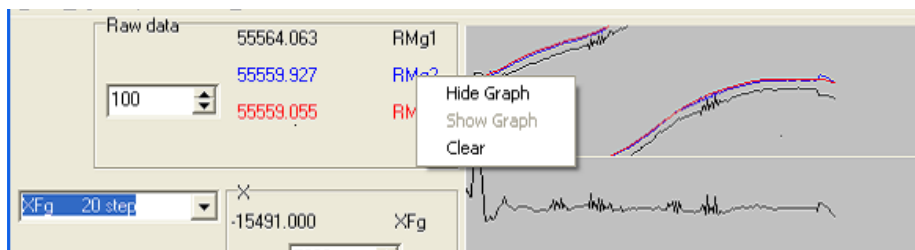


Heading channel might be opened for assistance; place it in the bottom chart by selecting 'Other' radio button in Channel Type dialog box.

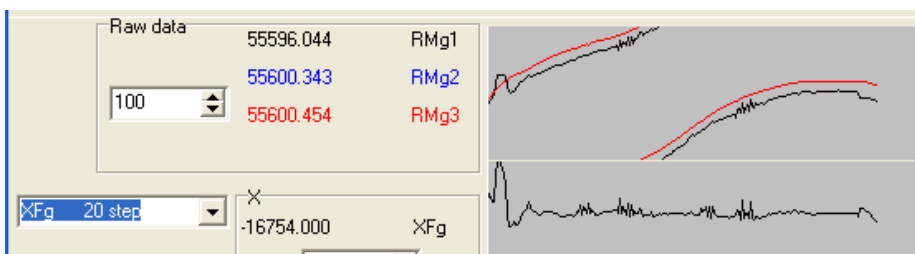
After all channels are selected screen will look similar to the following:



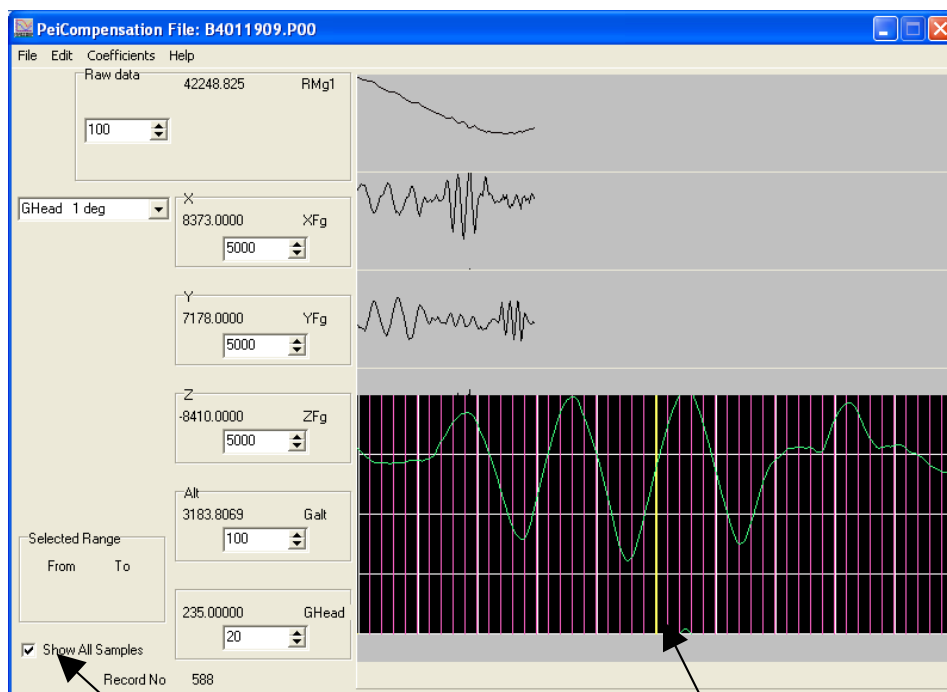
If more than one raw magnetometer data channel is present it might be difficult to view clearly all the graphs. It is possible to remove (clear), hide and show any raw magnetic data graph. Click with right mouse button (right-click) on the channel name label, pop up menu appears:



After 'Hide Graph' item is clicked, data channel is still selected but graph is not visible:



There is an option 'Show all Samples' that can be set with a check box located at the bottom left corner of the window. If this option is selected additional chart will appear when mouse pointer is placed over fluxgate channel or raw magnetometer data channel. This chart shows all samples of the current record.



Check box
'Show All Samples'

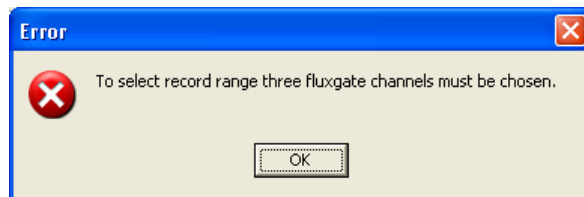
Additional chart

If all necessary data channels are selected the user can specify the record range that will be used for the coefficients calculation. Double click on any chart where the range begins (start record); the Records Range window will show up. The user can change record number value in this window.

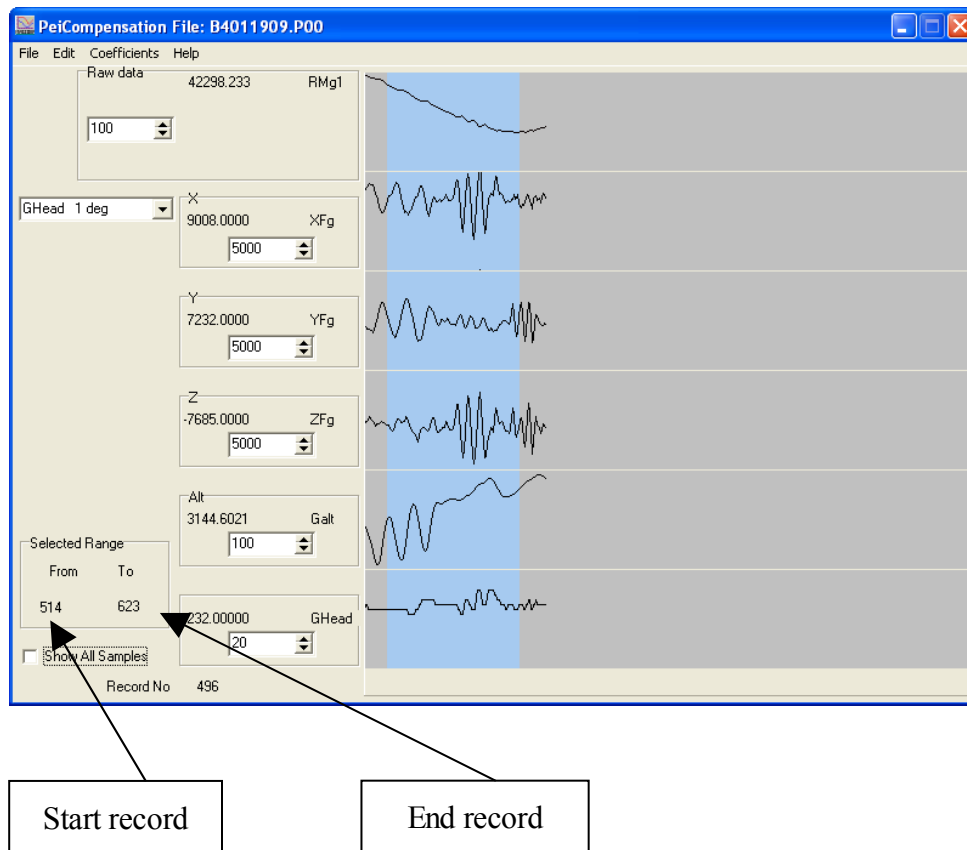


Repeat the procedure where the range ends (end record).

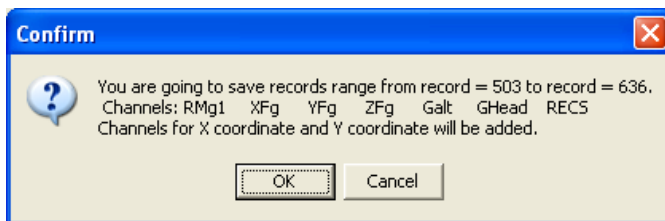
If any of magnetic channel is missing (not selected), the record range can not be specified. An error message will appear, for example:



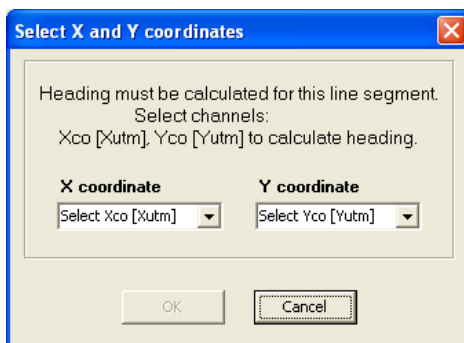
The selected record range is highlighted on the charts. Start and end records are indicated:



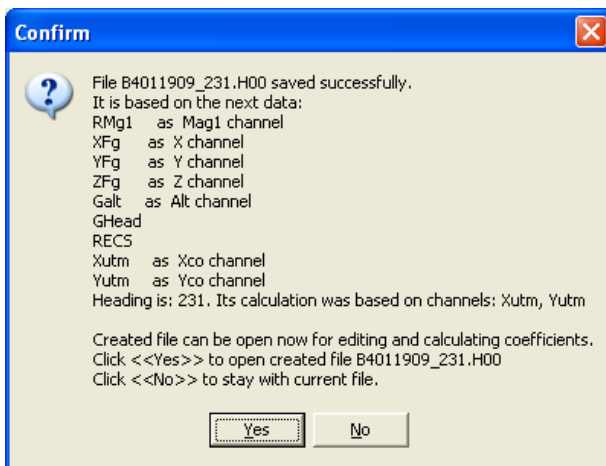
The following message appears to confirm the range saving:



If OK is clicked the user will be asked to select X coordinate and Y coordinate channels. They are used to calculate heading of the selected range that will be assigned to the set of coefficients.



When X/Ychannels are selected click OK. The range file will be saved:



If 'Yes' is clicked the source file will be closed. Created range file will be opened for coefficients calculating.

Note that Record channel (RECS) is always added to the range file even it was not selected by the user. Greated range file is named in the following way:

- Heading is added to the original file name
- Letter 'P' in the file extention is changed to 'H'.

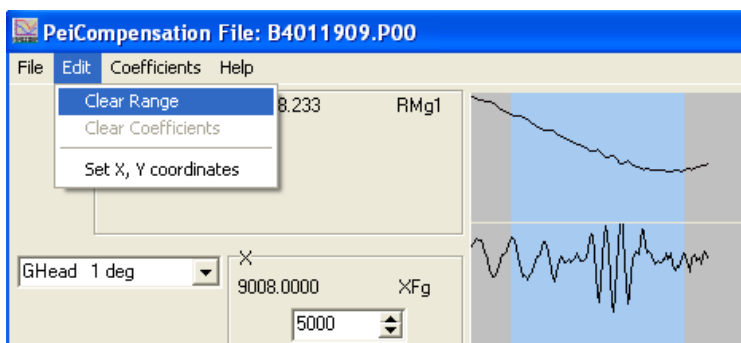
Range file header is similar to source file header but also contains heading information:

```

RECORDPEI definition:
MagComp Test Data, Heading: 232
This file was created from original data file B4011909.P00 on 6/15/2004
Channels Xutm Yutm were used for heading calculation.
BEGIN
RECS,1,li,1,0,,fiducial-records
Xutm,1,fl,1.0,0,m,Xutm
Yutm,1,fl,1.0,0,m,Yutm
Galt,1,fl,1,0,m,Alt
RMg1, 10,li, 0.00020,0,nT,Mag1
XFg, 10,in, 1.0,0.0,step,X
YFg, 10,in, 1.0,0.0,step,Y
ZFg, 10,in, 1.0,0.0,step,Z
END
    
```

2.2.2.1 Change Record Range

If necessary, the selected record range can be changed before range file is saved. Clear the selected range using 'Clear Range' item in the Edit menu:



A new range can be specified.

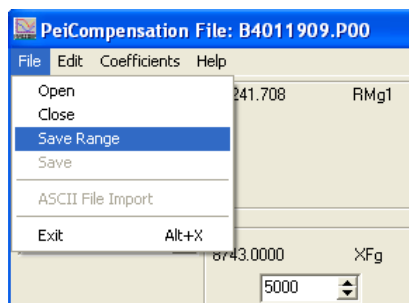
2.2.2.2 Change Selected Channels

If wrong data channel(s) was (were) included into a range file, a new file has to be created.

Use 'Select Channel' drop down list to select proper magnetic and altitude channels.

X and Y coordinate channels can be set using 'Set X,Y coordinates' item in the Edit menu.

When new selection has been made the range file can be saved using 'Save Range' item in the File menu:



2.2.3 Calculate Compensation Coefficients

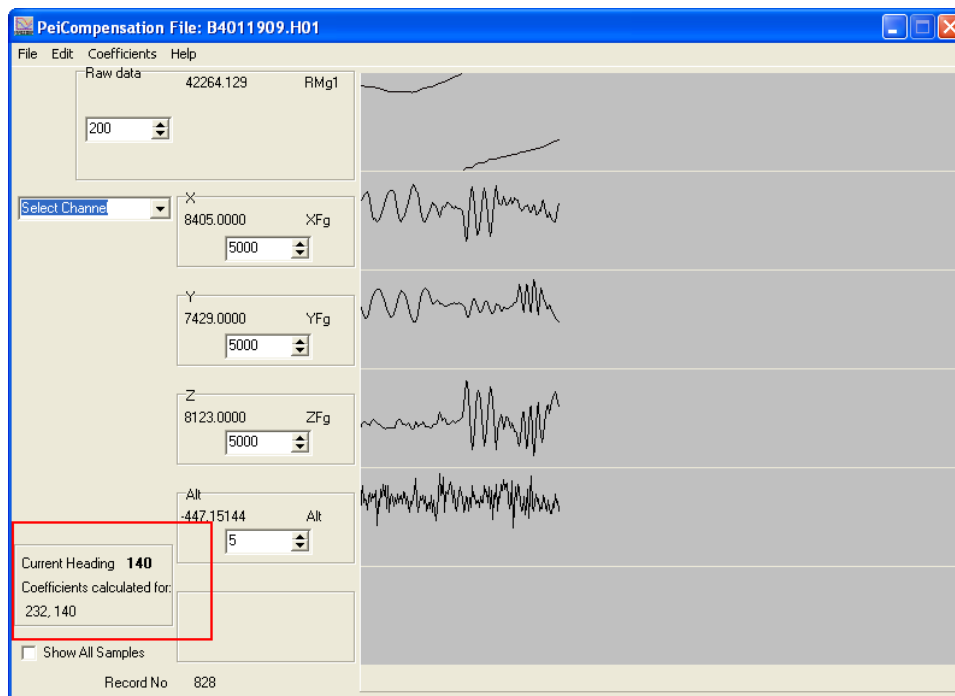
All four headings compensation coefficients have to be saved into one file. Each range file has to be opened and coefficients calculated.

When all available headings are processed, coefficient file has to be saved.

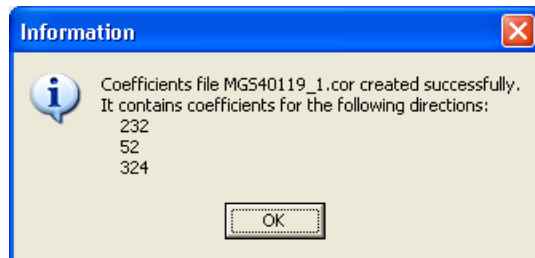
Do not save coefficient file of each heading separately.

Open a range file. Fluxgate (X, Y, Z) and raw magnetometer data channels are selected automatically and charts displayed. Coefficients can be calculated using item 'Calculate Coefficients' in the Coefficients menu.

Range file heading is displayed in the bottom section of the window. If coefficients are calculated the heading is added to the list of calculated headings:



When all headings coefficients are calculated use ‘Save calculation’ item in the Coefficients menu to save calculated coefficients into a coefficient file. The file name starts with ‘MGS’; the extension is ‘.cor’. The message similar to the following will appear:



2.2.3.1 Edit Range File

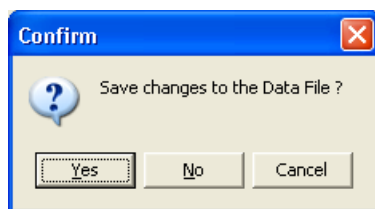
The data can be edited before coefficients are calculated. Click in a chart where correction is needed. Edit screen will appear:

RECS	Xutm	Yutm	RMq1	XFg	YFg	ZFg	Alt
903	536662.3125	3069466.75	42213.77453	9232	-6885	7627	-446.2633453
			42213.64933	9257	-6892	7585	-447.0034254
			42213.53113	9291	-6905	7544	-446.5316243
			42213.42053	9319	-6921	7503	-446.0690743
			42213.31673	9332	-6934	7467	-446.5223733
			42213.21553	9335	-6947	7434	-446.9849234
			42213.11293	9338	-6962	7402	-446.9756724
			42213.00753	9351	-6974	7374	-447.0589314
			42212.89733	9366	-6986	7350	-446.1153293
			42212.78193	9375	-7003	7334	-447.5029794
904	536726.375	3069516.25	42212.66053	9383	-7022	7320	-446.3188513
			42212.53213	9390	-7032	7307	-446.2818473
			42212.39993	9396	-7033	7295	-446.0690743
			42212.26533	9401	-7036	7291	-446.9571704
			42212.13013	9402	-7045	7293	-446.7628994
			42211.99413	9402	-7050	7292	-447.1421904
			42211.85813	9410	-7041	7282	-447.2439514
			42211.72373	9423	-7025	7267	-445.8007953
			42211.58993	9433	-7015	7255	-446.6148834
			42211.45533	9436	-7012	7247	-447.2254494
905	536790.4375	3069565.75	42211.31833	9434	-7010	7242	-446.9664214
			42211.17933	9436	-7009	7241	-446.4853693
			42211.03893	9440	-7012	7245	-447.0681824
			42210.89873	9445	-7020	7250	-446.3651063
			42210.76213	9449	-7027	7250	-446.1523333

Ten records data is displayed. When mouse pointer is moving over a chart, the corresponding record cell in spreadsheet is activated (record 904 on the picture above).

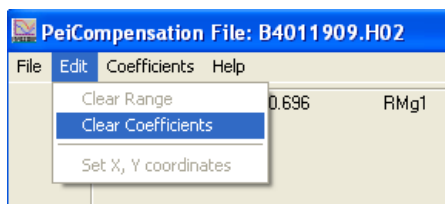
After editing; if OK is clicked data is saved in a buffer not into a file. This process can be repeated for all records that require correction. To save modified data in the range file use item ‘Save’ in the File menu.

If data was not saved in the range file after editing, the user will be asked to confirm changes before coefficients are calculated:

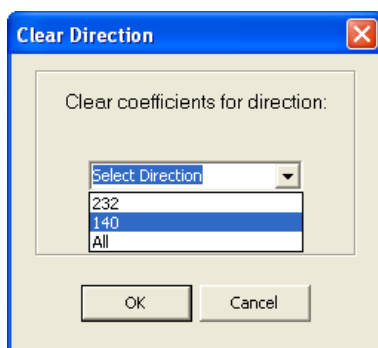


2.2.3.2 Recalculate Coefficients

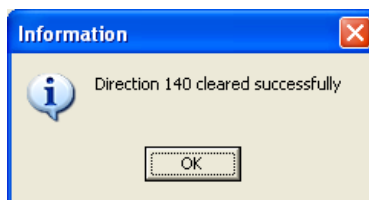
It is possible to remove coefficients of any calculated heading. Click on item 'Clear Coefficients' in the Edit menu:



Clear Direction window comes out:



Select required heading (direction) in a drop down window. All headings item can be also selected. Coefficients of the selected heading will be cleared:

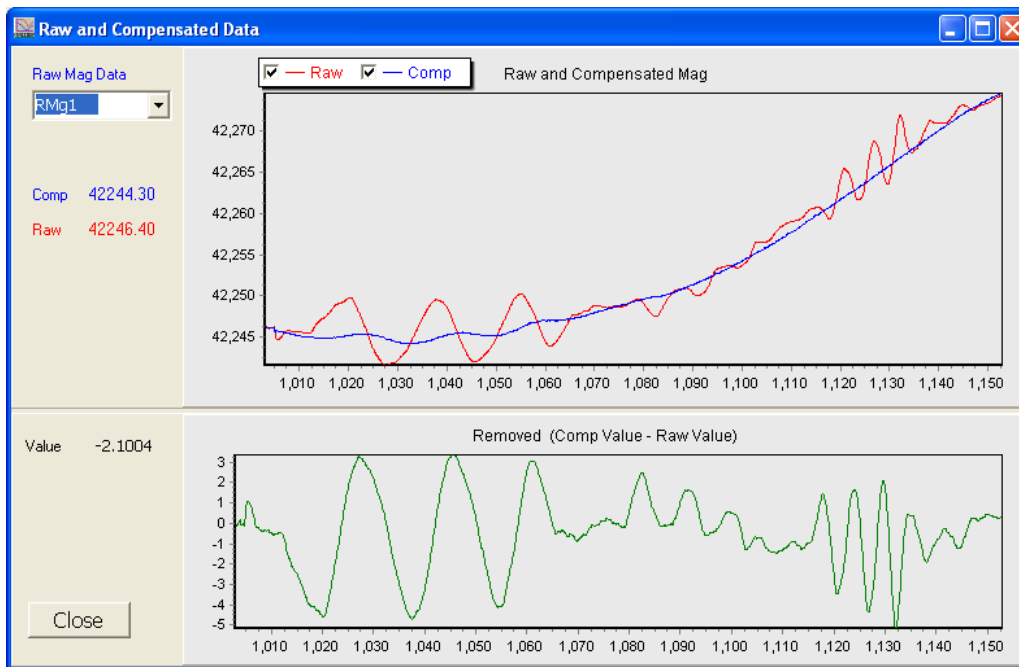


The user can then make any corrections to the data or selected record range and recalculate the coefficients.

2.2.4 Test Coefficients

The user can test calculated coefficients. Click on ‘Magnetic Compensation’ item in the Coefficients menu. This provision is enabled if a range file is opened in PEIComp.

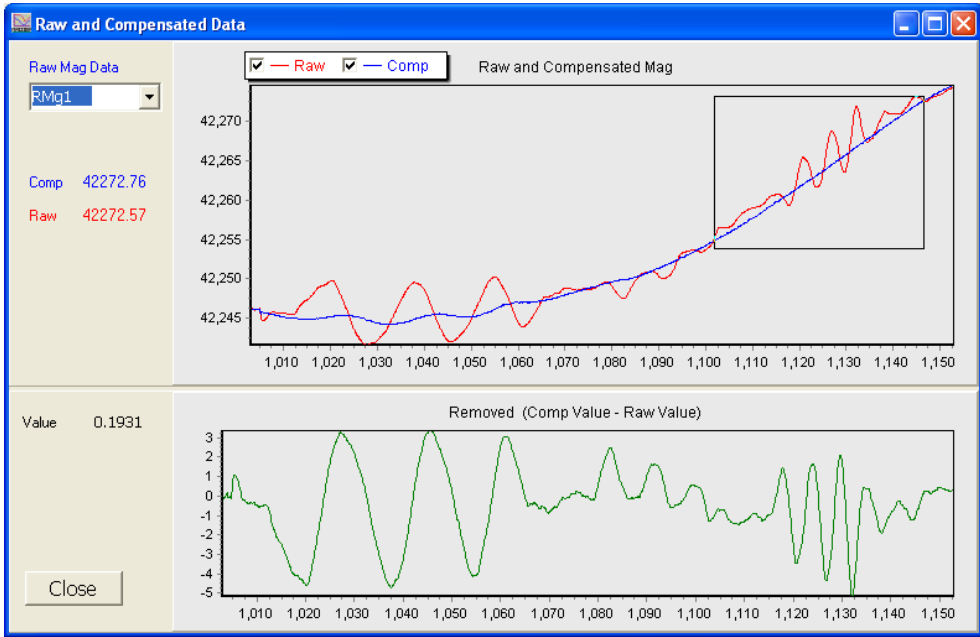
Raw and Compensated Data Charts will appear:



Raw and compensated magnetic data is displayed in the same chart. The bottom chart shows the difference between compensated and raw data. The horizontal axis represents record number. The units for the magnetic data is nT.

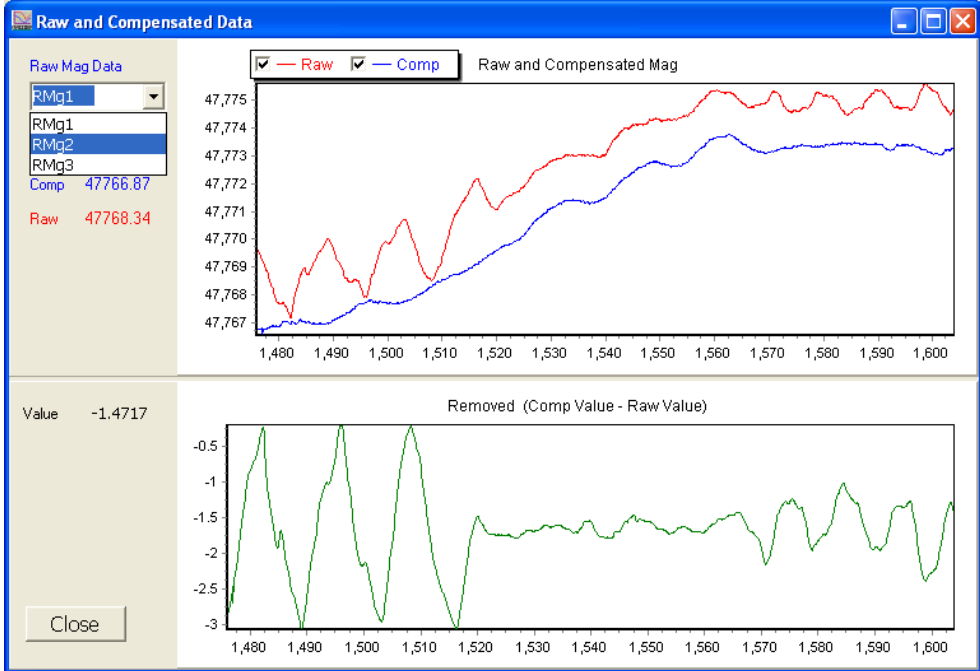
Data values are updated if mouse pointer is moving over the charts.

The charts can be zoomed in. Draw selection rectangle with left mouse button in the direction from the left upper corner to the right lower corner. This procedure can be applied several times if needed:



Draw selection rectangle in the opposite direction to return to the original scale (zoom out).

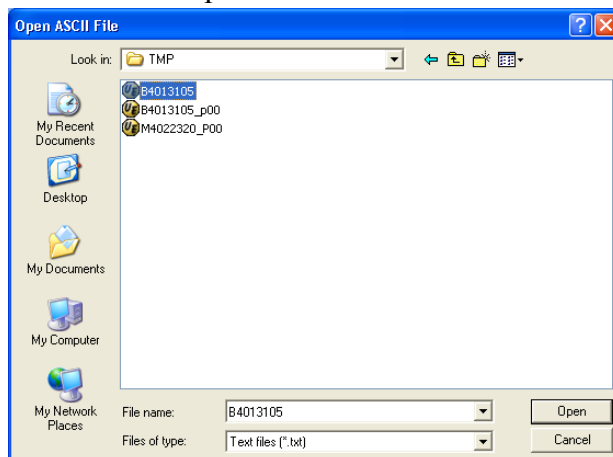
If more than one raw data channel exists in the file, select the next channel from the Raw Mag Data drop down window:



After all data was examined open another range file and repeat the test procedure for the rest of the headings.

2.2.5 ASCII Data Import

An ASCII data file can be imported by the PEICompensation program. PEI binary format file will be created. Click on the 'ASCII File Import' item in the File menu and select an ASCII file in the Open File window:



The ASCII data has to be organized into columns with the column headers at the top:

RECS	XCo	YCo	Mag	XFg	YFg	ZFg	Alt
1200	-2823974.17	4289019.59	47717.7510	-12408	-115	-9020	2825.59
*	*	*	47717.7644	-12417	-159	-9006	2825.13
*	*	*	47717.7668	-12426	-203	-8993	2826.06
*	*	*	47717.7660	-12434	-246	-8981	2825.59
*	*	*	47717.7752	-12440	-289	-8969	2825.59
*	*	*	47717.8098	-12447	-329	-8957	2825.13
*	*	*	47717.8618	-12457	-368	-8941	2825.59
*	*	*	47717.9070	-12472	-407	-8917	2825.82
*	*	*	47717.9260	-12492	-446	-8886	2825.36
*	*	*	47717.9198	-12514	-484	-8851	2825.36
1201	-2824032.84	4289057.46	47717.9004	-12535	-521	-8817	2826.06
*	*	*	47717.8816	-12554	-556	-8786	2825.59
*	*	*	47717.8584	-12571	-589	-8758	2825.59
*	*	*	47717.8290	-12587	-622	-8732	2825.36
*	*	*	47717.8000	-12600	-654	-8709	2825.59
*	*	*	47717.7882	-12612	-685	-8688	2825.36
*	*	*	47717.8014	-12624	-717	-8667	2825.59
*	*	*	47717.8302	-12638	-748	-8643	2825.59
*	*	*	47717.8506	-12653	-778	-8617	2825.36
*	*	*	47717.8494	-12669	-806	-8588	2825.82
1202	-2824091.08	4289094.96	47717.8282	-12685	-829	-8560	2825.36

Important. The Record number column is mandatory. Possible names of the column are: <RECS>, <FID> or <FIDS>. The record column values are consecutive whole numbers.

The following picture demonstrates an example of a text file to be imported by PEIComp. The data has different sampling rate:

- Alt – 1sps
- LA – 2 sps
- XCol, Ycol – 5 sps
- RMg – 10 sps

Note that the first row of each record has no asterisk:

RECS	XCo1	YCo1	Alt	RMg	LA
2786	386890.26	6600543.40	1150.80	55400.328	69.14
*	*	*	*	55400.082	*
*	386881.68	6600540.35	*	55399.840	*
*	*	*	*	55399.578	*
*	386873.25	6600537.31	*	55399.272	*
*	*	*	*	55398.924	69.69
*	386864.66	6600534.07	*	55398.552	*
*	*	*	*	55398.156	*
*	386856.08	6600531.03	*	55397.728	*
*	*	*	*	55397.252	*
2787	386847.49	6600527.98	1151.00	55396.734	70.91
*	*	*	*	55396.200	*
*	386838.90	6600524.94	*	55395.664	*
*	*	*	*	55395.144	*
*	386830.32	6600521.89	*	55394.667	*
*	*	*	*	55394.246	72.24
*	386821.73	6600518.84	*	55393.870	*
*	*	*	*	55393.522	*
*	386813.15	6600515.80	*	55393.172	*
*	*	*	*	55392.814	*
2788	386804.56	6600512.750000	1151.10	55392.461	73.34

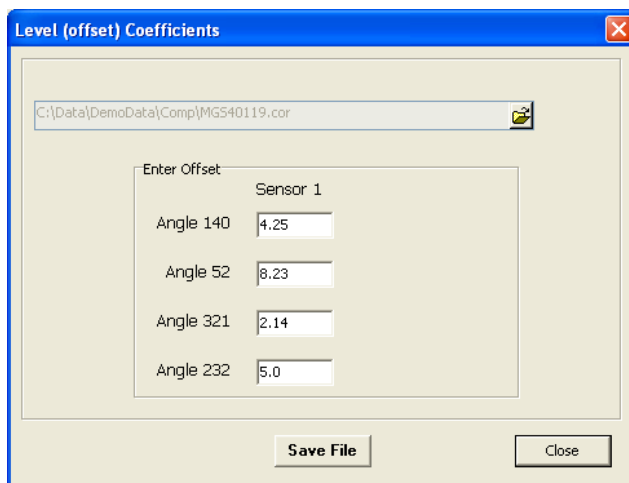
A new file created in PEI binary data format and contains float type (8 bytes) data. This file can be opened by PEIComp application and used as source data for the calculation of the coefficients.

2.2.6 Set Level (Offset) Coefficients

When coefficient file is created the level coefficients are set to zero. There is provision in the program to assign level (offset) coefficient of each heading in the coefficient file.

Click on 'Level Coefficients' item in the Coefficients menu, the Level Coefficients window appears. Select the desired coefficient file using the 'Open File' icon. Only the files with extension '.cor' can be selected.

Enter offset values of each heading (angle) in the corresponding edit box and save the file:





A new coefficients file will be created. The user can test this file by running magnetic compensation and view compensation result. See section 2.2.4 for the details.

3 APPENDIX A: CONTACTS

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