

GCM/HEM Workflow guide in Aarhus Workbench

- from import to processed data

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Introduction

This guide will give information on how the workflow from import of raw data to processed data can be done in Aarhus Workbench.

Version information

This manual is written for Aarhus Workbench 5.4

GCM/HEM equipment

There are many different types of GCM/HEM instruments e.g.:

- DualEM systems
- Geonics EM systems
- Iris Promis system
- GF Instruments CMD systems
- TerraPlus GEM systems
- CGG Resolve system

Example files can be downloaded at www.aarhusgeosoftware.dk

In general, for all systems is that they use electromagnetic induction to estimate the resistivity of the ground. They have one transmitter coil and several receiver coils. There are 3 main things that has influence on the sensitivity of the depth:

- **Distance between receiver and transmitter coils**
Most systems have a distance of 1, 2 or 4 meters between coils, but others have up to 100m
- **Coil configuration**
There are many names to describe the coil configurations depending on if you describe the configuration of a coil pair or each individual coil. We describe each individual coil with respect to the moving direction x:

HMD-x: Horizontal Magnetic Dipole in the x-direction (X).

HMD-y: Horizontal Magnetic Dipole in the y-direction (Y).

VMD: Vertical Magnetic Dipole (Z).

Possible coil pairs supported in Aarhus Workbench:

HMD-x, HMD-x (x,x) corresponds to vertical coaxial (VCA)

HMD-y, HMD-y (y,y) corresponds to vertical coplanar (VCP)

VMD, VMD (z,z) corresponds to horizontal coplanar (HCP)

VMD, HMD-x (z,x) corresponds to perpendicular (PRP)

- **Operating frequency**

Some systems are only operating with one frequency and then different spacing and coil configurations. Other has a sweep of frequencies on the same spacing and configuration.

Data

Aarhus Workbench supports 3 types of data units:

- **Apparent conductivity** in **mS/m** with in-phase ratio of the secondary to primary magnetic field in parts per thousand (**ppt**). Inversion is only available for the apparent conductivity, but the phase can be plotted in the processing window.
- **Apparent resistivity** in **ohmm** with in-phase ratio of the secondary to primary magnetic field in parts per millions (**ppm**). Inversion is only available for the apparent resistivity, but the phase can be plotted in the processing window.
- **In-phase** and **quadrature parts**, both in **ppm**. Inversion is available for both parts.

Data in conductivity will be converted to resistivity during import by:

$$\sigma_a = \frac{1}{\rho_a} = \frac{4}{\omega \mu_0 s^2} ppm \cdot 10^{-6}$$

Where s is the coil distance, $\omega = 2\pi f$ where f is frequency and $\mu_0 = 4\pi 10^{-7}$.

Data file format

Aarhus Workbench can import data in xyz format. Non-data lines can be ignored if they have a common sign in the beginning of the line, e.g. /. This sign can be set in the importer. Lines starting with "LINE" will be used during import and inversion to divide data into lines. Data columns are mapped during import along with all the system settings.

The coordinate systems supported for GCM and HEM data is either UTM or lat/long which can be converted to UTM during import.

Standard deviations and noise

Both a relative, absolute and user standard deviation can be added to the data, along with a standard deviation from the meaning in the processing. The user standard deviation is added if the user manually changes the standard deviation of selected data points in the edit window.

Noise from a GCM/HEM instruments is typically additive compared to the direct measured response which normally is given in ppm. So to calculate the noise the data values have to be converted into ppm if they are not already) by:

$$ppm_{measured} = \frac{1,974 \cdot f \cdot s^2}{\rho_a}$$

And then the total standard deviation for e.g. 5% relative noise and 1 ppm absolute noise can be calculated by:

$$\sigma_{data} = \sqrt{0,05^2 + \left(\frac{1 \text{ ppm}}{\text{ppm}_{m\ddot{a}lt}}\right)^2}$$

In Workbench we add 1 to the calculated number, so a value of 1.05 equals 5%.

All together the standard deviation for a data point is calculated as:

$$\sigma_{data} = \sqrt{\sigma_{stack}^2 + \sigma_{relative}^2 + \sigma_{absolute}^2 + \sigma_{user}^2}$$

NOTE: For data in resistivity or conductivity, a higher absolute standard deviation value gives a smaller calculated standard deviation and vice versa. This is due to the conversion to ppm.

Data example

```

/UTMX      UTMX      Elev  Heig  Rhoa1  Phase1  Rhoa2  Phase2  Rhoa3  Phase3  Rhoa4  Phase4  Rhoa5
Phase5  Rhoa6  Phase6
5.532216e+005 6.211351e+006 24.94  0.285 82.6446 -0.00018 181.8182 -0.00092 66.6667 -0.00011 114.9425 -0.00469 59.5238 -
0.00172 76.9231 -0.01389
5.532216e+005 6.211352e+006 24.9359 0.285 83.3333 -0.00017 178.5714 -0.00088 66.2252 -0.00011 117.6471 -0.00440 59.8802 -
0.00173 76.3359 -0.01264

```

Data example with format of ppm and latitude/longitude coordinate system

```

/ID Lat      Long      I_3330Hz Q_3330Hz I_8250Hz Q_8250Hz I_20370Hz Q_20370Hz I_47970Hz Q_47970Hz I_93030Hz Q_93030Hz
Sensorheight
4  43.812355  -79.092895 3.59E+02 6.08E+01 1.48E+02 -2.67E+02 -4.25E+02 -9.26E+01 -1.48E+03 3.76E+03 1.92E+03 5.70E+03
1.0
5  44.263275  -79.119545 3.70E+02 6.29E+01 1.42E+02 -2.84E+02 -4.15E+02 -9.99E+01 -1.48E+03 3.77E+03 1.91E+03 5.71E+03
1.0

```

Data example with format of mS/m and UTM

```

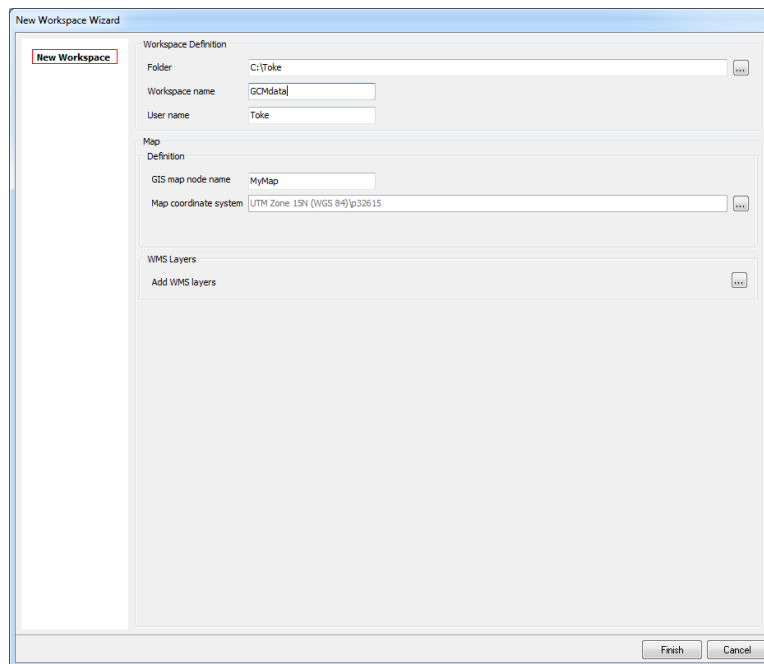
/Station  POINT_X  POINT_Y  10m_vmd  10m_hmd  20m_vmd  20m_hmd  40m_vmd  40m_hmd  sensorheight
0         390117.806 6459461.9481.8 -0.2      7.3      5.7      64.4     55.5     0.7
10        390111.068 6459455.4530.9 0.2       7        5.5      59.4     53.6     0.7

```

Step by step guide

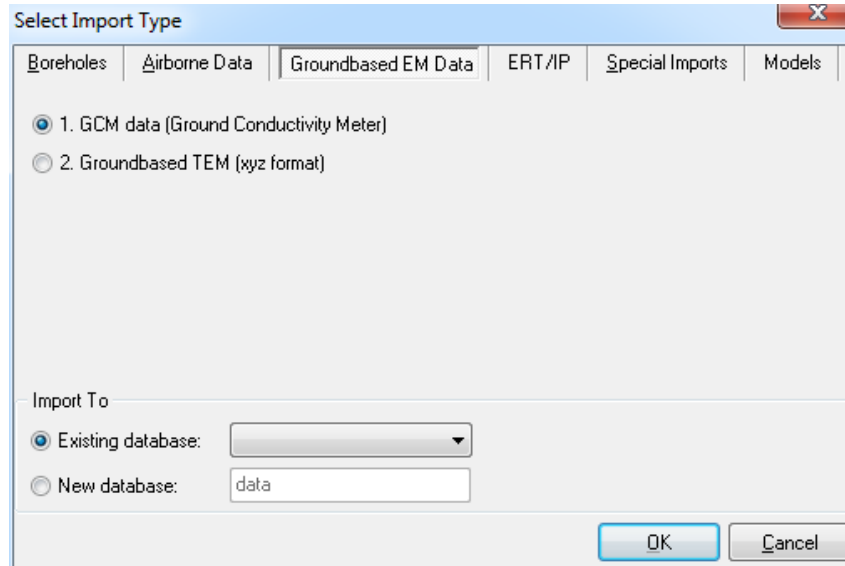
Create new workspace and import data

1. Open Aarhus Workbench and press New. Create a new workspace and choose a coordinate system. For GCM/HEM data it has to be a UTM system.

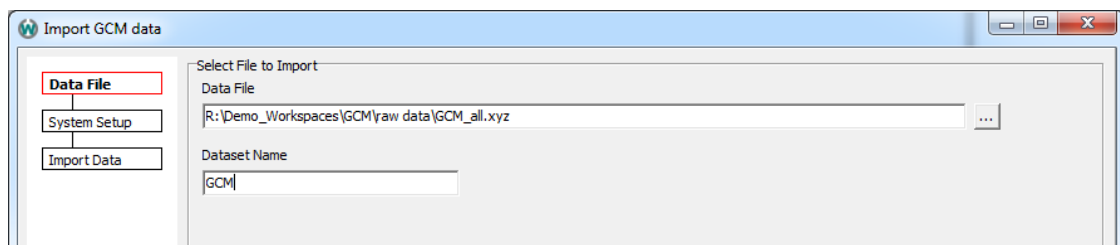


2. Add WMS server if needed and press finish and create a new Workbench database.

- Now the main Workbench windows open, with the GIS interface. Highlight the “Geophysics data” in the left tree and go to Database tab and press import. A window will open with several options. Choose either “GCM data” from the Groundbased EM Data tab or “Frequency domain Hem data” HEM from the Airborne tab. Tick off “New database” and press ok.



- The import window will now open. Load the data file and give the dataset a name. Press next to go to the system setup and data mapping.



Then the system setup needs to be specified. There are templates for many different GCM/HEM systems in the Workbench installation folder under ‘Workbench\ImportSettings\GCM\’ or ‘Workbench\ImportSettings\HEM\’.

Enter the number of coil configuration on the system. The table will expand/decrease with the chosen number.

As default there is added a 5% standard deviation to the data.

- **Frequency:** write the frequency for each configuration
- **Coil sep. [m]:** write the inter-coil distance
- **Tx and Rx orientation:** Describe the coil orientation with X, Y and Z as described in the introduction.

- **Abs std:** Add an absolute standard deviation if needed. Read the note in the introduction if an absolute standard deviation is added for data in resistivity or conductivity.
- **Data unit:** Define the data unit from the dropdown menu.
- **Sensor height (only for GCM):** write the height of the Rx sensor. This value should be as precise as possible since the inversion takes the height into account. The higher the sensor is from the ground the more information is lost in depth.
- **Dummy value:** Set a dummy value if one is used in the data file. Lines which has this dummy value will be ignored.
- **Import every:** Choose to import every data point or only every second or third etc.
- **Comment line:** Ignore lines which starts with the selected sign during mapping and import.
- **Coordinate system:** Choose the coordinate system for the data.
- **Transform coordinates on import:** Only used if data is in lat/long and needs to be formatted into UTM.

Import GCM data

Data File
System Setup
 Import Data

Coil Configurations

Number of Coil Configurations

Relative STD (Rhoa)

Relative STD (Phase)

Coil configurations

Ch.	Frequency [Hz]	Coil Sep. [m]	Tx Orient. (X,Y,Z)	Rx Orient. (X,Y,Z)	Abs. STD [Ohmm]	Abs. STD [ppm]
1	9000	1.00	Z	Z	0.00E+00	0.00E+00
2	9000	1.10	Z	X	0.00E+00	0.00E+00
3	9000	2.00	Z	Z	0.00E+00	0.00E+00
4	9000	2.10	Z	X	0.00E+00	0.00E+00
5	9000	4.00	Z	Z	0.00E+00	0.00E+00
6	9000	4.10	Z	X	0.00E+00	0.00E+00

System

Data Unit

Sensor Height [m] Dummy value

Import every data points Comment Line

Coordinate System

Import data file coordinate system

☐ Transform coordinates on import

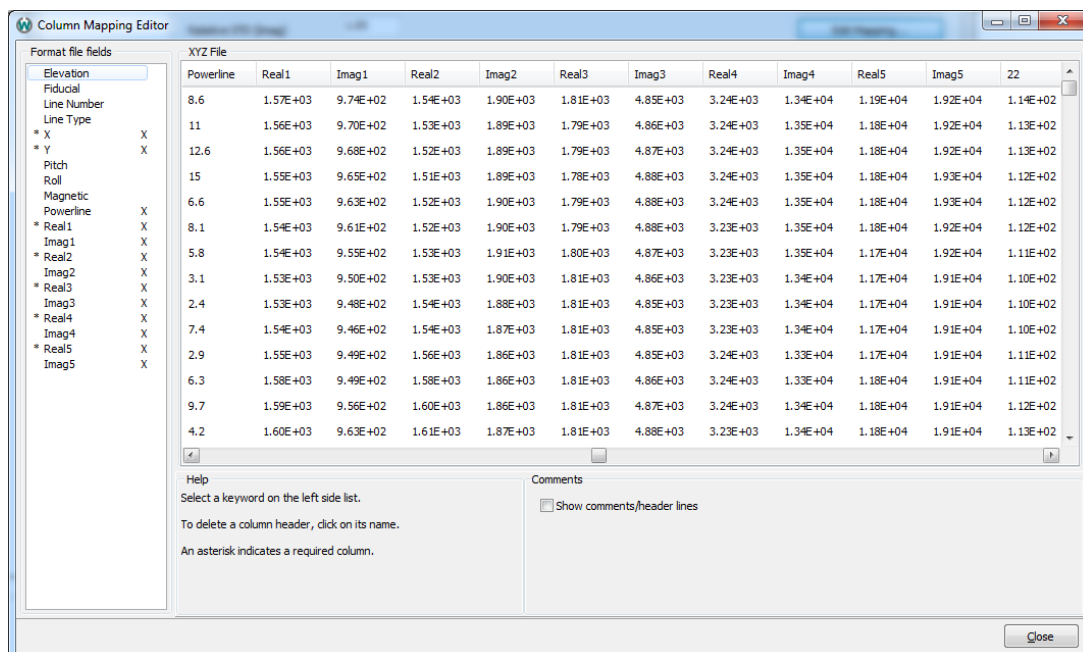
New coordinate system

Save Settings...
 Load Settings...
 Edit Mapping...

<< Back Import Cancel Help

Mapping of data columns

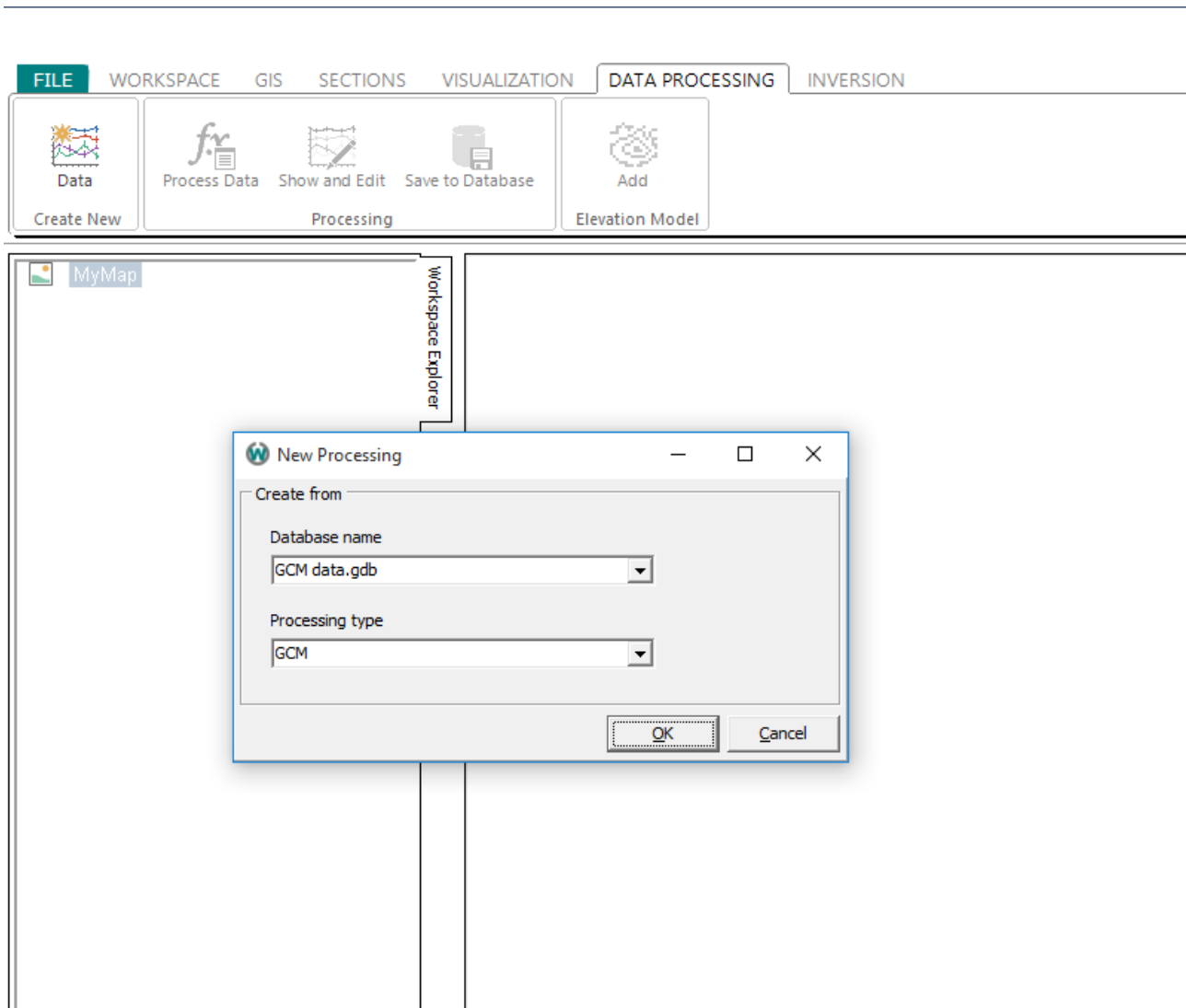
- After the system setup, click the 'Edit mapping...'
- Here the user has to map the data from the data file. To the left there is a list of information that can be mapped. Only information with * in front has to be mapped.
- Click the first information that needs to be mapped, e.g. the X-coordinate.
- Now click the uppermost cell in the column where the x coordinate is. An X will appear in top of the column.
- Now map the rest of the data and click 'close' and the mapping is saved.
- Before importing the data, the user can save the system setup along with the mapping by the 'Save settings..' button.
- Click 'Import' to import the data.



Create data processing node and process data

A window will pop up and ask if a processing node should be created. Click yes, choose map and choose dataset name and name of processing node. In the Workspace Explorer the processing node is now visible.

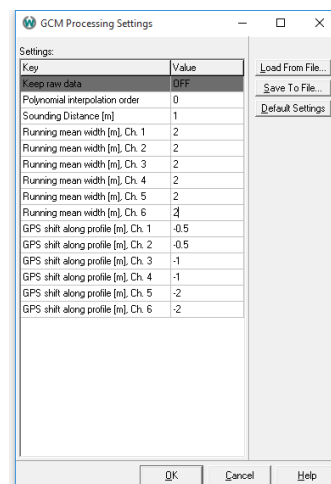
Another way to make a new processing node is to go to Data Processing tab and click Create New Data.



- Click the GCM/HEM node and press 'Process data'
- A window opens with processing settings. Settings can be saved and loaded from files. The normal workflow here is to set some processing values that the user thinks are ok. Then plot the data, and if e.g. the running mean is to low or high, go back and change the processing settings etc. until good processing settings are found.
NOTE, when changing the processing settings, the manual processing will be lost. So, it is important to find the settings that the user want to use before starting on the manual processing.

- **Keep raw data:** Keeps the raw data from import. All the below processing options are neglected..
- **Keep negative data:** Negative data will not be removed automatically. To use negative data, the inversion has to be run in linear space which can be changed during inversion setup.
- **Polynomial interpolation order:** With a setting of 0, the processing uses the running mean instead. With a value of 1 or more it tries to fit the data to a polynomial of order 1 or 2 etc. In general, we suggest using the running mean.
- **Sounding distance [m]:** Sets the sounding distance for the processing. The length should be more than the average sounding distance when the measurements where done in the field.
- **Running mean width [m]:** sets the running mean for each channel. The value has to so small that geological features are not smeared out, but also big enough the mean out noise variations in data. This setting often must be change several times before the manual processing to find the correct values. Each channel can have different value since some channels can be noisier than others.
- **GPS shift along profile [m]:** Change the GPS point in the direction of the profile. A negative number is moving the GPS point towards the moving direction.
 Often the GPS point is located at the transmitter or receiver coil, but the focus point of the measurement is in reality closer to the center between the receiver and transmitter. So the user has the possibility to shift the GPS point towards the middle.


- Press 'Ok' to do the processing of data.



Add data to GIS map

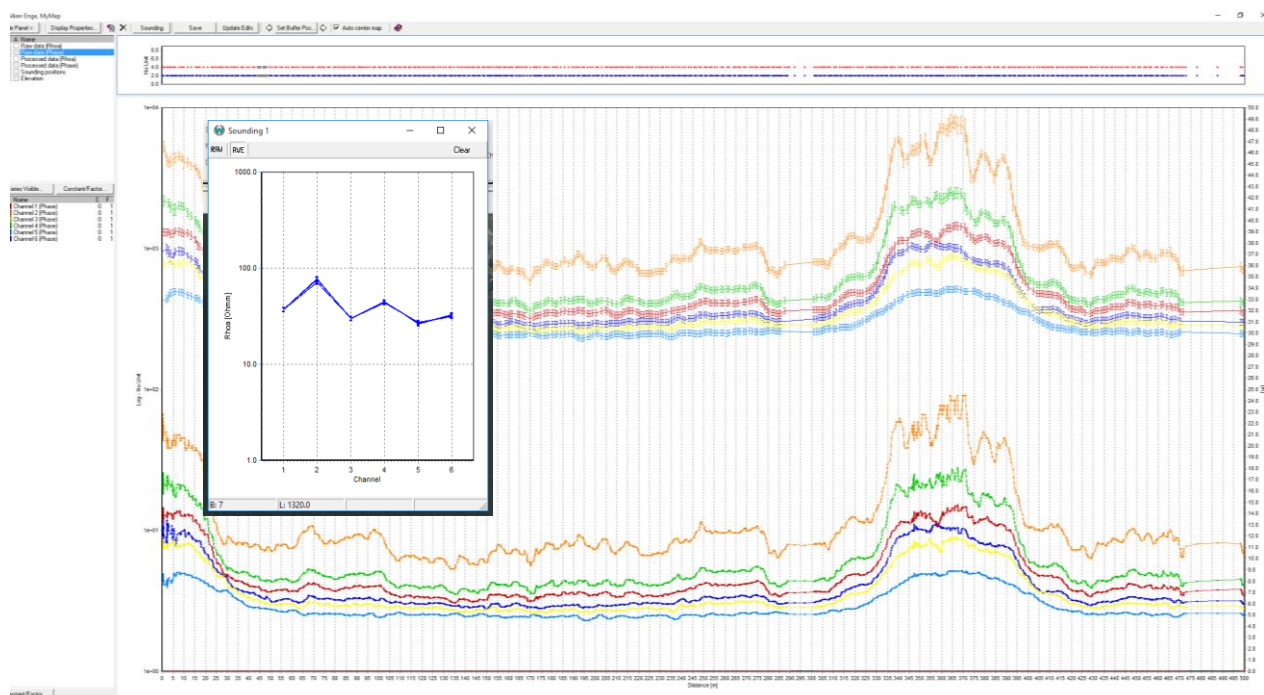
- Now the data has been processed, the data node can be expanded in the workspace explorer and the user has the option of adding the raw or processed data to the GIS interface.
- Click the box beside the node name and the node will be added to the GIS layer manager to the right. Clicking the box here will add the data to the map.
- The color of the data on the GIS map can be changed by highlighting the data node in the Workspace explorer and go to the Workspace tab and click 'Edit display'.



- Other GIS maps (.tab, .mif, .shp, .jpg., .tif etc.) can be added to the GIS interface by clicking the  icon in the lower right corner.



- Now it is time for the manual processing. Click 'Show and edit' in the 'Data processing' tab.



Edit window

The edit window is now open and the data is plotted.

- In the top right, the user can click raw and processed data on/off by clicking the box under V. E means editable and needs to be enabled if users want to make manual processing.
- The data can be shifted in the plot window so it is easier to see both raw and processed data at the same time. This is done by clicking the 'Constant/factor' and shift the selected data by a constant or factor.
- The user can also turn on elevation, mag data, powerline etc. if it is imported.
- Below in the bottom right, the user can switch channels on/off.
- By clicking 'Sounding' a sounding plot is opened. Soundings can be added to the plot by drawing a square at the top window in the Edit window where the sounding positions are.

Manual processing

- For processing, the user selects data on the data plot by drawing a square or just clicking with the mouse.
- Data can be set to in use (Alt+A) or not in use (Alt+Q) using the icons in the Chart tool on the main Workbench Window.
- Standard deviation on the selected data points can be changed (Alt+1-9) by clicking the 'Change Errors' icon on the Chart tool.
- You will notice when moving the mouse over the data points, a red dot will move along on the GIS interface since they are integrated into each other. This makes processing much easier when the user knows where the data is located and if the user have maps of powerlines, roads etc, these maps can help to see if data is couple due to these noise sources. Then the user can disable the selected data.
- In the GIS tab, the function 'Find Nearest' gives the user the possibility to click on data on the GIS map and the Edit window will go to the selected data point.
- Normal procedure is to remove couplings form the raw data. The changes in raw data is updated in the processed data by clicking 'Update edits' in the Edit window.
- Then remove noisy data from the processed data.
- When processing is done, close the Edit window and the user will be asked to save the changes made.

Inversion

- After processing, the data is ready for inversion. For inversion guides see <http://wiki.hgg.au.dk/do/view/Workbench/GuideInversions>