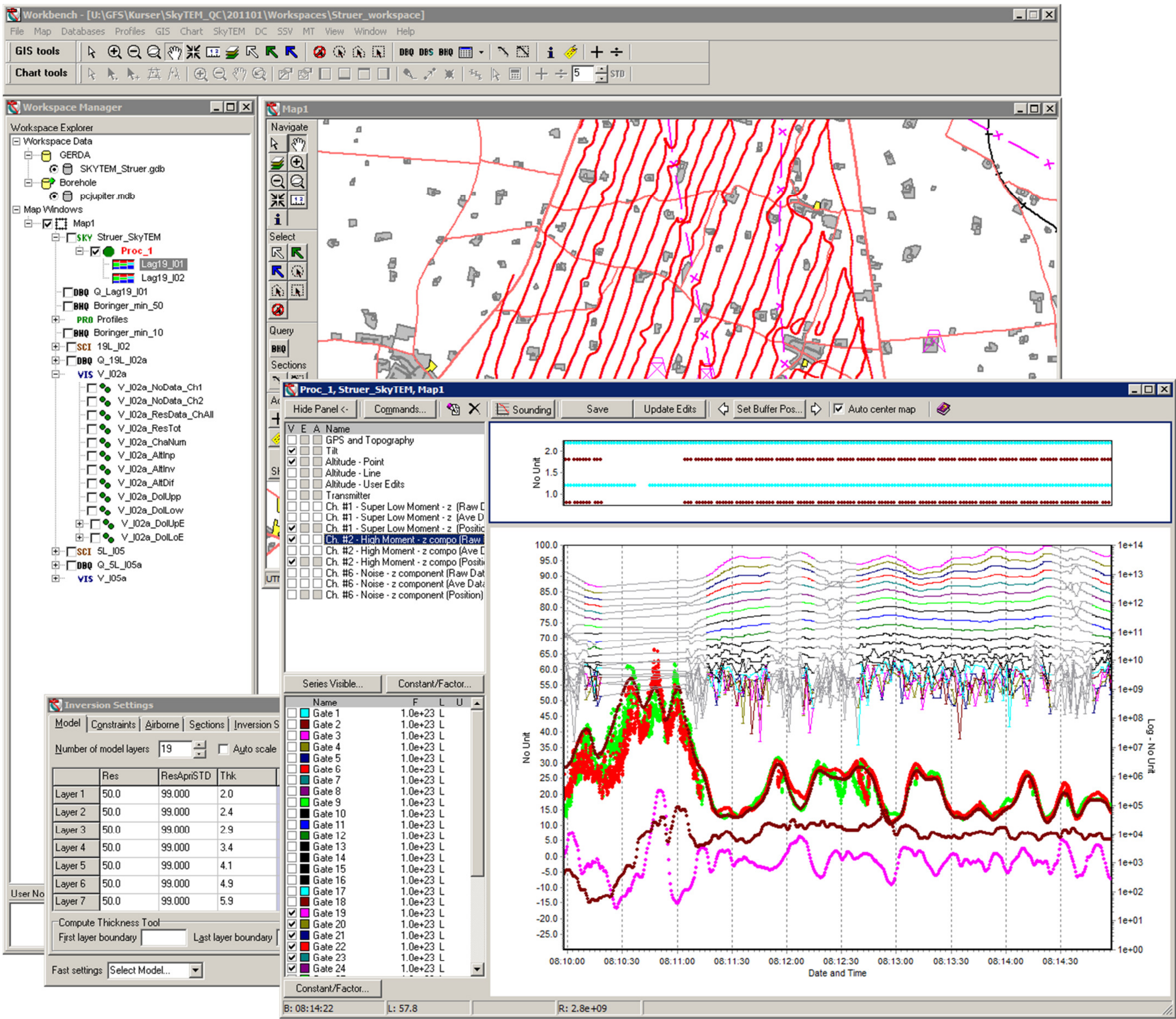
# Guide for processing and inversion of SkyTEM data in the Aarhus Workbench

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# 1. INTRODUCTION

The purpose of this document is to support the processing and inversion of SkyTEM data using the program Aarhus Workbench. A basic knowledge of the SkyTEM method, and some familiarity with Aarhus Workbench, is assumed. A detailed description of the SkYTEM-method is found in reference (GeoFysikSamarbejdet, 2003) while the TEM method in general is described in reference (HGG, 2004).

The document "Guideline and standards for SkyTEM Measurements, processing, and inversion" (HGG, 2010) contains key information about the SkyTEM system, data processing and inversion. The document also includes documentation of the SkyTEM file format and recommended processing and inversion settings, which therefore is not included in this Aarhus Workbench guide document.

A general help to Aarhus Workbench, e.g. how to set up a workspace, can be found in "Aarhus Workbench A-Z reference" (Geofysiksamarbejdet, 2007).

**Workflow**
The first step of working with SkyTEM data is data import, which is described in chapter 4. The processing is divided into two steps, an automatic and a manual part, (chapters 5 and ◎). Chapter 7 (SCI) and 8 (LCI) gives a description of the inversion set-up for SkyTEM-data. Additional help can be obtained from the help function in the application.

**Version 2.0:**
- All chapters are completely revised.
- SCI-inversion setup and inversion exception are added.
- Description of prior options in SCI-inversion is added.

# 2. FILE FORMATS AND TYPES

The following gives an overview of the output file formats of the SkyTEM system. During import to Aarhus Workbench the information from the different files are linked together and stored in a database.

The data recorded during a SkyTEM survey are reported in the file formats listed below.

- Geometry file (*.geo). One file per survey
- SPS-files (*.sps). Typically one file per flight
- SKB-files, (*.skb). Typically one file per flight
- Line number file (*.lin). One file per survey

A detailed description of the file formats is found in "Guideline and standards for SkyTEM Measurements, processing, and inversion, appendix 2", (HGG, 2010)

The skb-files contain voltage data from the receiver along with relevant information of the receiver and transmitter set-up. GPS-positions, altitudes, transmitter currents, pitch, roll etc. are saved in sps-files.

The Geometry-file holds information of the SkyTEM system, and the line number file (*.line), states line numbers and production intervals.

## 2.1 Geometry file

The geometry file contains information of the configuration of the SkyTEM system. This information is used during data processing and inversion. The geometry file is loaded with the remaining data in the Aarhus Workbench. It is a requirement that the final geometry file is delivered along with the remaining data. A complete description of the geometry file is available in (HGG, 2010), appendix 3.

The geometry file contains information of

the position of the various devices on the transmitter frame.

- the expected transmitter current. Any deviation from the actual applied current may not exceed 25% of the expected transmitter current
- the size of the transmitter coil, number of turns and the area
- calibration constants in the form of time and dB/dt factors and constants
- specification of the first usable gates of each channel (moment)
- low-pass filters

- the position of the front gate in time. The front gate shall occur at least 1µs before the first usable gate open time
- the estimated attenuation of the primary field from the zero position
- repetition frequency. Note that the repetition frequency stated in the geometry file is calculated as: RepetitionFrequencyGeo = 1/(4 x On-Time)
- parameters describing the waveform (turn-on and turn-off process). The turn-off process must be terminated before the front gate time (as stated above).
- uniform data STD. As standard, 3% is used
- gate centre times, gate factors, and gate open and close times.

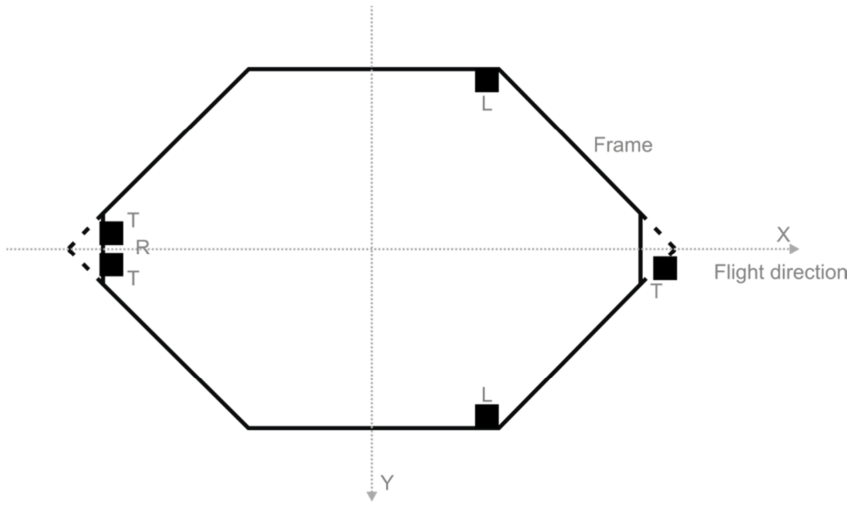



*Figure 1. Sketch of the SkyTEM frame from above with indication of the primary instruments and definition of x and y directions. The x axis is the flight direction, the Y axis points to the right, and the Z axis points into the page.*

## 2.2 SPS files

The SPS files contain:

- GPS data
- Pitch and roll (angle data)
- Altitude data
- Transmitter data, including transmitter current

The instruments used to measure these data are normally duplicated (except for the transmitter). Where possible, data from both instruments should be used.  All strings of the SPS file carry a GMT time stamp.

The coordinate system for the GPS data of the SPS file is lat./long. WGS84. GPS data should be measured by minimum one GPS, and any periods without recorded data should not exceed 10 s.

The angle measurement device is level (horizontal) with the transmitter frame/receiver coil with 0° for the x and y angles in the horizontal position. The X angle (pitch) is the flight direction, which is positive when the front of the frame rises and the rear end moves downwards. The Y angle (roll) is the inclination measured perpendicular to the flight direction. This angle is negative when the right side tilts upwards (see Figure 1).

The flight altitude is normally measured using two independent lasers. The resolution is 1 cm, and the uncertainty of measurements is in the order of 30 cm over a reflected surface.

The complete documentation of the SPS file format appears from (HGG, 2010), appendix 3.

### 2.3 SKB files (*.skb)

The SKB files contain the TEM data (dB/dt responses). The data are stored in a binary format with an ASCII header.

The complete documentation of the SKB file format is available from (HGG, 2010), appendix 2.

### 2.4 Line number file (*.lin)

The line number file states the line numbers and production intervals to be imported. For documentation of the lin-file format, see (HGG, 2010), appendix 2.

# 3. DATA PROCESSING – WORKFLOW

In the following, the overall requirements and measures related to data processing are outlined. Processing is performed using the SkyTEM processing module of the Aarhus Workbench. The recommended settings for each individual processor are stated in (HGG, 2010), appendix 5.

It should be stressed that the recommended data processing settings need to be adjusted to the mapping area, the geological setting, flight speed, mapping focus, etc. The person processing the data must ensure that the processing settings are adequate and have been adapted to the data set in question.

Generally, the processing of SkyTEM data should include.

- Review of the raw data delivery; geometry file, line number file, etc.
- Review of calibration soundings and reference measurements
- Processing of GPS angle and altitude data, including a visual assessment and editing along the profiles
- Processing of dB/dt data - automatic
    - Adjustment of the settings for the automatic processing. This procedure should account for the amount of removed data and the signal-to-noise ratio
    - Verification that all data are included and coincide with the data comprised by the raw data report
- Processing of dB/dt data - manual
    - Visual assessment and editing along flight lines
    - Elimination of coupled data
- Preliminary smooth inversion to support processing.

An outline of the SkyTEM data processing is available in references (GeoFysikSamarbejdet, 2006) and (An integrated processing scheme for high-resolution airborne electromagnetic surveys, the SkyTEM system, 2009). Furthermore, the help function of the Aarhus Workbench comprises a description of each processing setting.

# 4. DATA IMPORT

The following section is an introduction to the SkYTEM data import to Aarhus Workbench step.

Data are imported to databases in Firebird/Interbase format. Before importing data, a GERDA database must be created. GERDA databases have their own node in the **Workspace Manager**. A GERDA database is created/connected by right-clicking on the GERDA node. Only one GERDA database can be active at a time. The database is activated by clicking the marker beside the database. Data can only be imported to the active database.

**Import of SkyTEM data**

To initiate data import, open **File**/**Import** in the Aarhus Workbench top menu. The **Select Import Type** form opens. Go to the **Airborne** tab sheet and select ad 1: **Import SkyTEM raw and navigation data**. Press the **OK** button, and the **SkyTEM Data Import** window opens, see Figure 2. The SkyTEM Data Import Window, Creation of GERDA data set used to create data sets in the database before the import of SkyTEM raw data..

Import of SkyTEM is a two-step process:

1. Firstly, an entry in the database must be created, the "data set" level. The data set is the overall level holding important information of the data that will later on be imported, processed and inverted, e.g. names and equipment information. This means that all data belonging to the same data set must have the same system set-up, e.g. geometry file. A data set will typically consist of one survey.
2. Secondly, data are imported and marked as belonging to a data set in the database. Note: It is possible to later on import additional data to an existing data set. Therefore, keep data from the same survey area in the same data set when possible.

**Creation of data sets – step 1 (Figure 2)**

The first step in the import process is to create a data set that will hold the data:

1. Highlight the **Creation of GERDA...** radio button in the top of the **SkyTEM Data Import** window.
2. Locate the geometry file. Pressing the **View** button will bring up a text editor where it is possible to view and validate the file. Please note that validation is a check of syntax errors only.
3. Create a data set by highlighting the **New dataset** radio button

4. Press the **Settings** button to open the **SkyTEM Dataset Settings** window. Enter a name for the dataset, add various information of data processing and acquisition (not required), and most important, specify in which coordinate system data should be stored in the database. Note: SkyTEM GPS data are by default gathered in latitude-longitude WGS84. During import all coordinate information is transformed to the selected coordinate system, and this cannot be changed later.
5. Press the **Import** button.

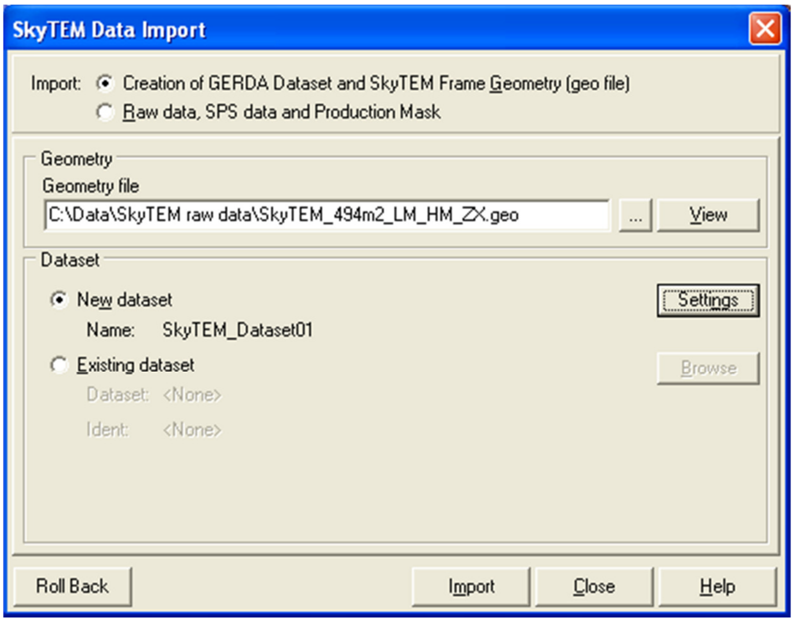



*Figure 2. The SkyTEM Data Import Window, Creation of GERDA data set used to create data sets in the database before the import of SkyTEM raw data.*

Some of the parameters in the geometry file cannot be changed after data have been imported to/processed in the Aarhus Workbench. Therefore, it is important that the geometry file is correct at the time of the import. Consequently, it may be advantageous to perform a minor inversion test on the data before initiating final data processing. This ensures that data are consistent and that inversion results are attainable given the employed system parameters.

**Importing raw data – step 2 (Figure 3)**
After creation of a data set (or multiple data sets), the following steps are used to import the raw SkyTEM data:

1. Highlight the **Raw data, SPS data...** radio button in the top of the **SkyTEM Data Import** window, Figure 2. This brings up the window shown in Figure 3.
2. Select target data set for the raw data in the **Dataset** section. If raw data import is initiated immediately after creation of a data set, this will already be selected.
3. Make sure the **Binary** button is highlighted.
4. Point to the parent folder with the skb-files and sps-files. It is only necessary to specify the parent directory in the Raw dir and SPS dir as the program automatically searches through subdirectories for files with sps and skb extensions.
5. Point to the production file holding the production intervals and line numbers (optional). Only data in the specified time intervals will be imported.
6. Press the **Import** button. This opens the **Import Software Channel Settings** window. Select which software channels to import. Only channels defined in the geometry file are present here. It is possible to have more channels defined in the geometry file than those you have recorded data from.

If **Detect and correct sign automatically during import** has been checked, the program will evaluate data before import and indicate whether a sign change of the voltage data is needed.

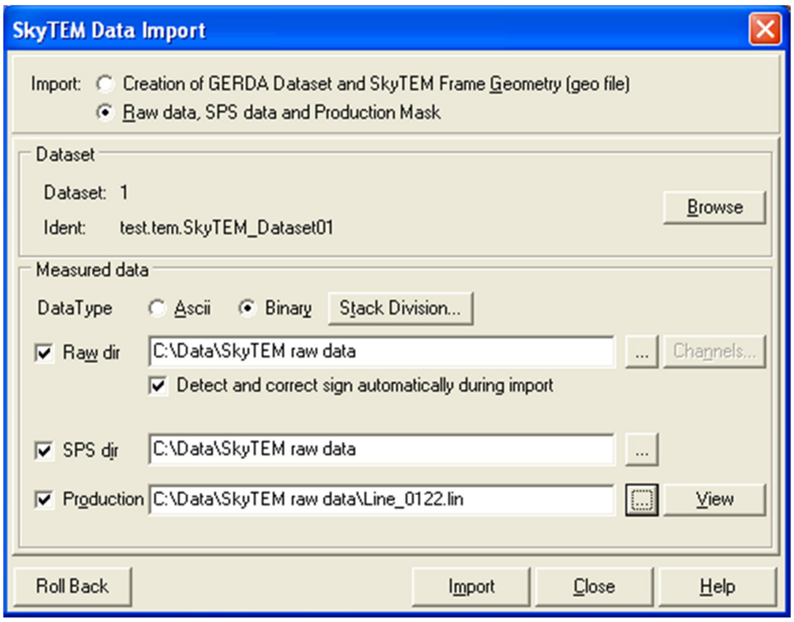



*Figure 3. The* SkyTEM Data Import Window, Raw data, SPS data... *used to import*

*SkyTEM raw data.*

**Division into substacks (Figure 4)**

These settings are for expert users only. The general user just needs to make sure that the *Divide instrument data stack into smaller…* is unchecked.

During import the individual transients are stacked into "raw stacks". Default raw stack sizes are given in the equipment set-up files. The default raw stack size ensures that the 50 Hz (or 60 Hz) power frequency is stacked out properly. Later in the processing, a user controlled stacking of the raw data into soundings is applied. However, it is possible to change the default raw stack size during import from the **Stack Division** form (Figure 4). Raw stack sizes are entered individually for each software channel. The field **Stack Size** determines the actual raw stack size. The original stack size must be a multiple of this, i.e. with a default stack size of 64, possible substack sizes are 32, 16, 8, 4 and 2. The original stack size is stated in the SKB-files.

The fields **Power Stack Size** and **STD Factor** are currently not in use.

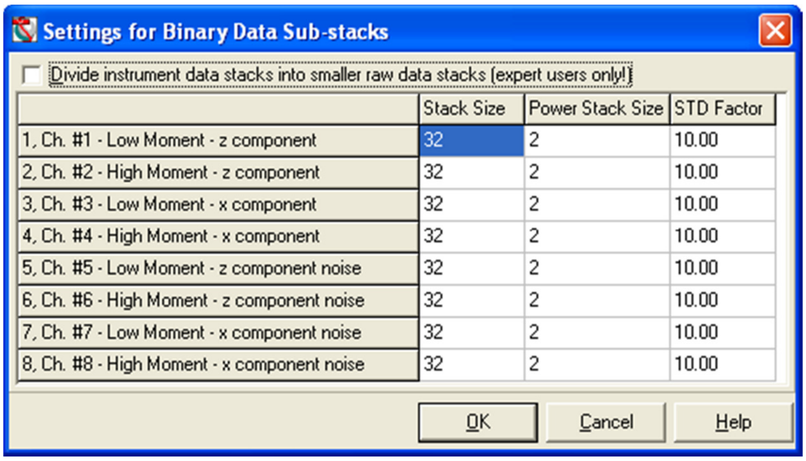



*Figure 4. The Settings for the Binary Data Substacks form where data can be divided into substacks.*

# 5. AUTOMATIC PROCESSING

This chapter will give a description of the automatic processing of SkyTEM data (GeoFysikSamarbejdet, 2006).

The automatic processing precedes the manual processing. It involves automatic filtering, averaging, etc. of data. The result of this should afterwards be inspected and adjusted from the **SkyTEM Edit Form**, which will be discussed later in this chapter. The automatic processing is based on a number of user-defined settings, but otherwise no manual corrections are made in this step.

The automatic processing mainly consists of five different processors representing the different data types.

Updated recommended processing settings are found in (HGG, 2010). Program default settings are found by pressing the **Default Settings** button. For an optimum use of the automatic processing, it is necessary to adjust the settings to the actual data set, the geological setting, flight speed, mapping focus, etc. The automatic processing can be considered as a possibility to get a good starting point for the more time-consuming manual processing. It is therefore advisable to put an effort into adjusting the settings to get an optimum automatic processing result.

**Processing start-up**

To initiate processing of SkyTEM data, the following steps must be taken:

1. Create a GIS Map if none is present.
2. Select the database with the data.
3. Right-click on the Map Node and select **Data processing/New SkyTEM processing**. This brings up the **Dataset Selector** window where data from the data sets in the database are selected. Only one dataset can be selected for each data processing.
4. Select which data set to use and enter a name for the processing. This creates a **Sky** Node, which is the link to the current data set in the **Workspace Manager**. All data imported as part of that particular dataset can be processed, and if needed, it can be divided into smaller processing nodes. Ticking the **Sky** Node in the **Workspace Manager** plots the raw GPS points on the map.
5. Right-click on the **Sky** Node and select **Process data** to start the automatic processing. This brings up the **New Processing** window, see Figure 5. The color bars show time intervals of the data in the database.

6. Specify which time interval to work on using the fields **From Time** and **To Time** or using the mouse. This creates a processing node subordinate of the **Sky** Node. Since SkyTEM processing is memory extensive, it is advisable to split a data set into processing nodes of approximately one day's production. Note: The user must keep track of which time intervals have been selected for processing and inversion.
7. When the time interval is specified, the **Processing Management** window is opened (see The Processing Management window), and settings for the automatic processing can be adjusted. The **Processing Management** window and the processors are described in detail below.
8. When the different processing settings are specified, select **Run**. It is always possible to go back and adjust the settings as manual processing may be overwritten (see The Processing Management window).  Try using the default settings for a start and then adjust the settings based on the output.
9. Go through steps 5-9 again to create more processing nodes until the full data set is represented in these.

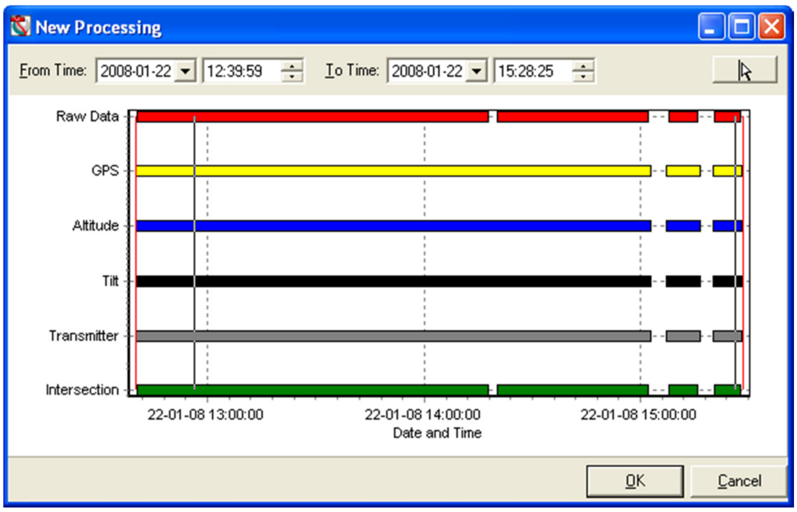



*Figure 5. The New Processing window specifying the time interval of the processing. Colorbars show the distribution of different data types: Red bar: Voltage data, yellow bar: GPS data, blue bar: Altitude data, black bar: Tilt data, grey bar: Transmitter data and green bar: the intersection between these.*

All data belonging to a processing Node must have the same processing settings. It is possible to use different settings for different processing Nodes, but normally you will find one set-up that works and then use this for all the processing nodes.

Making a new processing node can be thought of as making a copy of the raw data for the selected time interval. It is possible to make multiple processing nodes with e.g. different processing settings for a specific time interval.

Processing nodes can later on be deleted via the relevant right-click menu. It is possible to delete processed data from the database without deleting the raw data that form the basis of the processing node.

### The Processing Management window

This window (see Figure 6) is the control center of the automatic processing. In the top of the window, various information of the processing is displayed. The status of processing is either **New** (i.e. automatic processing has not been run yet) or, in case the automatic processing has already been run and settings are now being adjusted, the option of **Continue Processing** will appear.

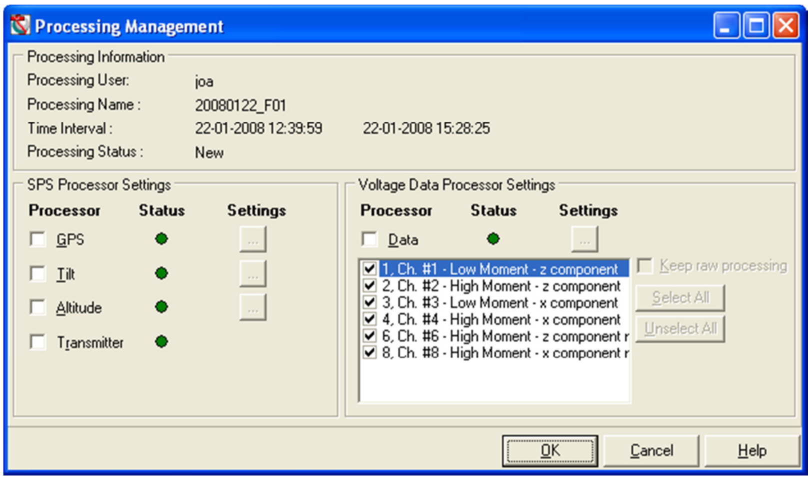



*Figure 6. The Processing Management window which forms the basis of the automatic processing of SkyTEM data.*

Five different processors are represented in the window, four concerning the SPS data and one concerning the voltage data. Each of these processors can be selected for automatic processing.

Note that there is a hierarchy of the processors. Both **Tilt** and **GPS** data must for example be processed first in order to process **Altitude** data since the latter is dependent on the two former. The processors also have a status bulb, indicating whether the processor is ready to be run for the first time (green bulb) or to be run again (yellow bulb). This indicates that it is possible to make a first run of only some of the processors, but leave out e.g. automatic processing of voltage data.

The **[...]** button brings up the settings window for each processor. They are described in sections 5.1 - 5.4. When the selected processors are run, any previous automatic or manual processing of these is by default overwritten. The result of the processing is saved in the database. The only exception to the overwriting of manual processing is the **Data processor**, where the user has the option to keep manual editions of Raw data even if the processor is rerun.

Information of settings of completed processing runs is available by selecting **Properties** in the right-click menu of the Processing Node.

The different types of SPS-files have different time stamps and are recorded with different frequencies. It is therefore necessary to set up a regular time array with a **Beat Time** frequency into which all data are averaged.

## 5.1 GPS data processor

GPS x- and y-positions are fitted separately with a polynomial. The settings for the GPS are shown in Figure 7 and commented in the table below. GPS data are required in order to use the dB/dt data.

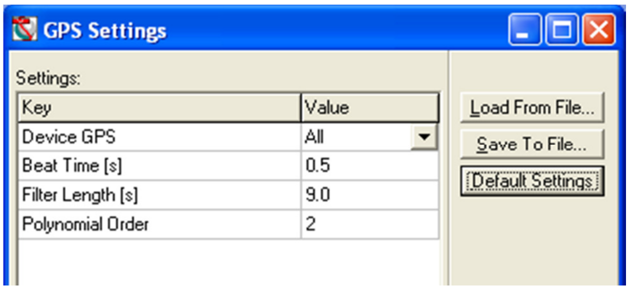



*Figure 7. The GPS processor settings.*

| GPS settings | Comment |
|---|---|
| Device | Use one or all GPS-devices |
| Beat Time [s] | Sample rate for the time array into which all navigation data (GPS, tilt, altitude) are averaged. |
| Filter Length [s] | The length of the filter for each polynomial fit. |
| Polynomial Order | The order of the polynomial |

*Table 1: GPS processor settings*

### Tilt data processor

The pitch (x-ang.) and roll (y-ang.) data are filtered by a median filter to eliminate potential outliers. Tilt-data are used to correct altitude and voltage data. The **Tilt settings** are shown in Figure 8 and commented in the table below.

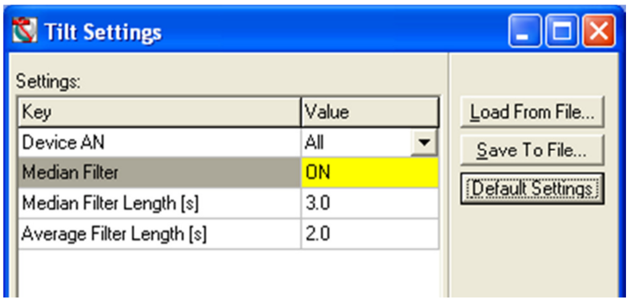



*Figure 8. The Tilt processor settings.*

| Tilt settings | Comment |
|---|---|
| Device | Use one or all devices |
| Median Filter | Turns the filter on and off |
| Median Filter Length [s] | Length of the filter |
| Average Filter Length [s] | Part of the data from Median Filter Length to use for in each step |

*Table 2: Tilt settings*

## 5.2 Altitude data processor

The transmitter altitude is acquired using a number of laser altimeters placed on the frame. They measure the distance to the ground can also be influenced by reflections from e.g. tree tops, bushes, etc., which results in a seemingly lower altitude. The main objective of altitude processing is therefore to remove reflections that do not come from the ground. Since the laser does not point vertically towards the ground when the frame tilts, an automatic tilt correction of altitude data is also applied. Furthermore, the final output altitudes for the TX- and RX-positions are calculated based on the position of the altimeters on the frame and the tilt.

Filtering of altitude data is done in two steps (passes 1 and 2) working separately on each altimeter device: Step one involves repeated cycles of fitting a polynomial to the data while continuously discarding outlying data, predominantly those of relatively low altitude. This carefully removes more and more undesired reflections. The polynomial fit is done in running time intervals controlled by the **First Filter Length** and **First Filter Shift Length** settings. The second step is a polynomial fit to remaining data from pass 1, where data are averaged and sampled to **Beat Time**. The Altitude settings are shown in Figure 9 and commented in the table below.

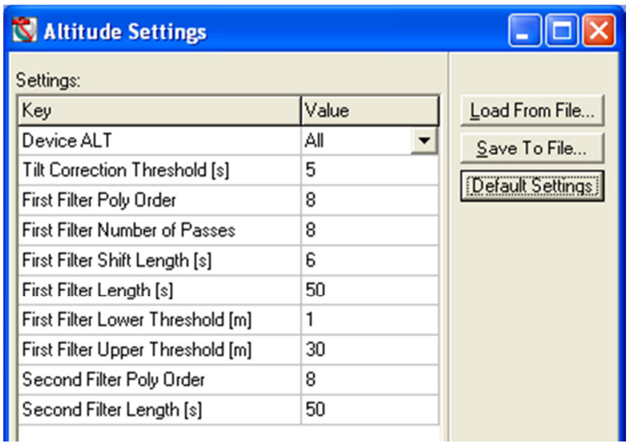



*Figure 9. The Altitude processor settings.*

| Parameters | Comment |
|---|---|
| Device | Use one or all devices |
| Tilt Correction Threshold [s] | If no tilt data are found within this time span, no tilt correction is made. |
| First Filter Poly Order | The order of the polynomial used in the first filtering of the altitude data |
| First Filter Number of Passes | Number of times (passes) the first polynomial fit is applied. |
| First Filter Shift Length [s] | Time interval used for evaluation (center par of Filter Length). |
| First Filter Length [s] | Time interval for each polynomial fit. |
| First Filter Lower Threshold [m] | Data that are below the polynomial minus the threshold value are discarded before the next pass. (reflections from tree tops etc.) |
| First Filter Upper Threshold [m] | Data that are above the polynomial plus the threshold value are discarded before the next pass. (incorrect readings from altimeter) |
| Second Filter Poly Order | Order of the polynomial used to fit the remaining data from the first filtering. |
| Second Filter Length [s] | Time interval for each polynomial fit. |

*Table 3: Altitude parameters*

### 5.3 Transmitter data processor

There are no settings for this processor.

### 5.4 DB/dt data processor

In the following the term coupled data will refer to data being influenced by biased man-made noise, e.g. power lines, whereas noise filled/noise influenced data will refer to data being influenced by random EM-background noise.

The objective of the dB/dt data processing is to remove any coupled data from the raw data before stacking the data into soundings (Average data, AVE). After the raw data stacking, a very noisy late-time data point holding a very limited earth response is culled in the average data.

**Automatic processing**

During the automatic processing, a number of filters are used to remove coupled and strongly noisy data. Furthermore, data are adjusted to compensate for the transmitter loop and receiver coil deviations from the horizontal position. The automatic processing should not be expected to remove all coupled data/noisy data. In some cases the automatic processing discards usable data, it is therefore necessary to manually revise and adjust the automatic processing result. The amount of data discarded by the automatic filters depends on the filter settings. To operate optimally, the filters need to be adjusted to the specific data set/area.

A step in the automatic processing consists of defining settings for the averaging of raw data to create soundings. The Data processor settings form is shown in Figure 10 and commented in Table 4. The Settings must be set individually for each software channel.

The processing is done in three steps: Firstly, coupled raw data are culled, secondly, remaining data are averaged and thirdly, noise-filled averaged data are culled. This is done using a number of filters and averaging mechanisms that work separately on each software channel.

Two different sets of filters are used in the data culling:

- **Cap filter**: These filters work on raw data with the purpose of culling coupled data before averaging, i.e. culled data are removed and therefore not used in the averaged data stacks. Whether data are noise-filled/noise-influenced should *not* be assessed on raw data stacks since data averaging increases the signal-to-noise ratio. The **Cap Filters** evaluate data above an assumed noise level (user defined). It is recommended to set the assumed noise level conservatively to avoid noise-filled raw data to be detected as coupled data and to minimize the risk of interpreting noise-filled data as coupled data.

- **Ave Filters**: Are deployed on averaged data with the purpose of culling noise-filled data, i.e. it is assumed that coupled data have been removed from the raw data stacks before this evaluation. **Ave Filters** work on the entire data curve.

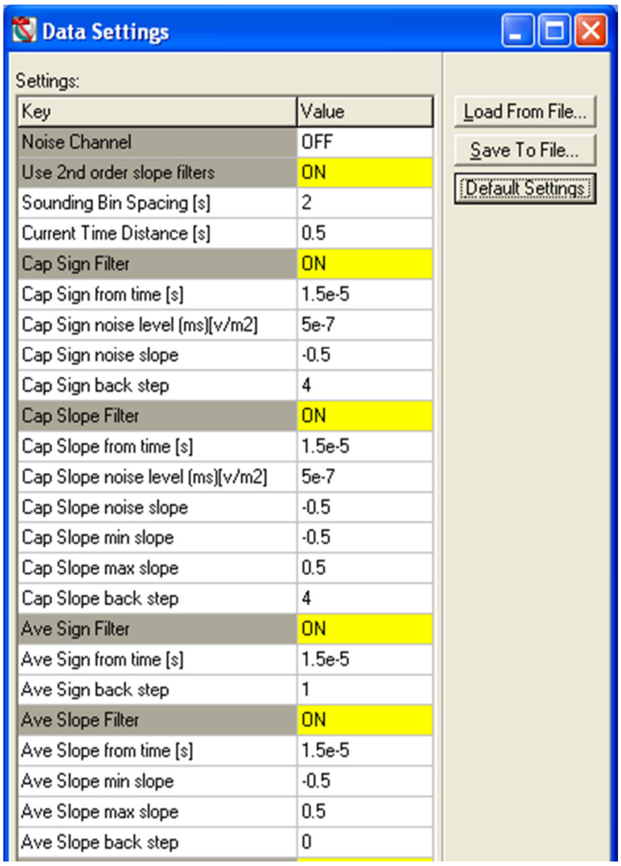



*Figure 10. The Data processor settings top part*

| Parameter | Comment |
|---|---|
| Noise Channel | Define if the Channel is a Noise channel or not. |
| Use 2nd order slope filters | ON: all Slope Filters will be based on the change in slope of the dB/dt sounding curve ("2nd order derivate"). When OFF, all Slope Filters will be based on the slope of the dB/dt sounding curve. |
| Sounding Bin Spacing [s] | Not in use, but included for compatibility reasons. |

| Parameter | Comment |
|---|---|
| Current Time Distance | Not in use, but included for compatibility reasons for old data. |
| Cap Sign Filter | Sign filters cull data if a sign change is found. |
| Cap Sign from time [s] | Data points before this time are not evaluated by the sign filter. |
| Cap Sign noise level (ms) [v/m2] | Defines the assumed noise level at 1 ms. Data points below noise function formed by the noise level and the noise slope are not evaluated. |
| Cap Sign noise slope | Defines the slope of the noise function. |
| Cap Sign back step | Number of additional data points to be removed from the data curve counting backwards. |
| Cap Slope Filter | Sets filter on/off. Slope filters cull data if the slope or the change in slope (2nd order slope ON) of the dB/dt sounding curve is not within specified min/max slopes interval. |
| Cap Slope from time [s] | Data points before this value are not evaluated by the filter. |
| Cap Slope noise level (ms) [v/m2] | Defines the assumed noise level at 1 ms. Data points below noise function formed by the noise level and the noise slope are not evaluated. |
| Cap Slope noise slope | Defines the slope of the noise function. |
| Cap Slope min slope | Defines the smallest acceptable 1$^{st}$ or 2$^{nd}$ order derivate of the dB/dt sounding curve as selected with Use 2$^{nd}$ Order Slope filters. |
| Cap Slope max slope | Defines the maximum acceptable 1$^{st}$ or 2$^{nd}$ order derivate of the dB/dt sounding curve as selected with Use 2$^{nd}$ Order Slope filters. |
| Cap Slope back step | Number of additional data points to be removed from the data curve counting backwards. |
| Ave Sign Filter | Sets filter on/off. Sign filters cull data if a sign change is found. |
| Ave Sign from time [s] | Data points before this value are not evaluated by the filter. |
| Ave Sign back step | Number of additional data points to be removed from the data curve counting backwards. |
| Ave Slope Filter | Sets filter on/off. Slope filters cull data if the slope or the change in slope (2$^{nd}$ order slope ON) of the dB/dt sounding curve is not within specified min/max slope interval |
| Ave Slope from time | Data points before this value are not evaluated by the filter. |
| Ave Slope min slope | Defines the smallest acceptable 1$^{st}$ or 2$^{nd}$ order derivate |

| Parameter | Comment |
|---|---|
| | of the dB/dt sounding curve as selected with Use 2nd Order Slope filters. |
| Ave Slope max slope | Defines the maximum acceptable 1st or 2nd order derivate of the dB/dt sounding curve as selected with Use 2nd Order Slope filters. |
| Ave Slope back step | Number of additional data points to be removed from the data curve counting backwards. |

*Table 4: dB/dt parameters*

The filters work from gate to gate, i.e. they evaluate the sounding curve from gate n to n+1, then from n+1 to gate n+2, etc. **Cap** and **Ave Filters** are divided into **Sign** and **Slope Filters**. The Sign filters cull data if they are negative. The slope filters cull data if the change in slope (**Use 2nd order slope filters** = On) of dB/dt data curve does not fall within the user defined interval. A change in slope is evaluated on a log-log dB/dt plot.

If the **Use 2nd order slope filters** are set *Off*, the slope evaluation is done on the absolute dB/dt slope (not recommended).

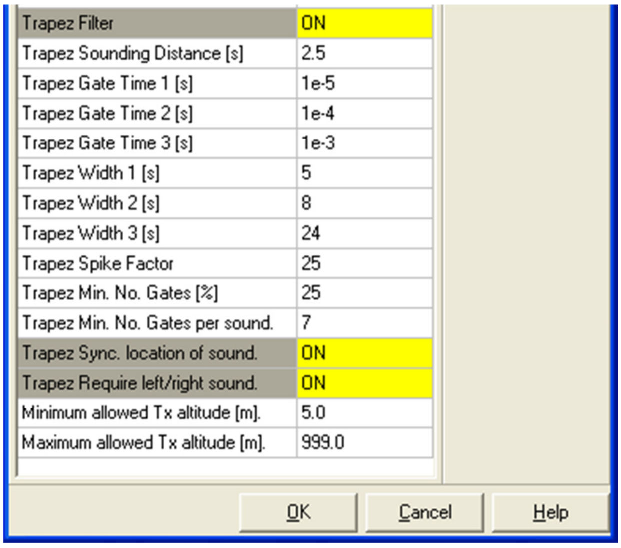
**Example (2nd order derivate = On)**

The slope filter makes an evaluation of the change of slope between gate [n, n+1] and [n+1, n+2] etc. If minimum slope is set to -0.5 and maximum slope to 0.5 and the difference in slope between [n, n+1] and [n+1, n+2] is >0.5 or >-0.5 data is culled.

The slope and sign filters cull data from the first detected sign change or first non-valid change of slope to the end of the data curve. Furthermore it is possible to cull earlier data points with the **step back** settings.

**Averaging/Stacking**

The purpose of averaging raw data to create soundings is to improve the signal-to-noise ratio. It is therefore important that noise-filled data are not removed from the raw data before the averaging step whereas coupled data must be culled in the raw data before averaging. The averaging is done with a trapezoidal shaped filter, in which late-time data on the data curve are averaged over a greater interval than early-time data, as shown in Figure 11. The width of the filter is defined stepwise at three gate times. A non-spike filtering is also applied for each gate time in the averaging process. Settings for the averaging are shown in Figure 11 and explained in Table 5.



| | |
|---|---|
| Trapez Filter | ON |
| Trapez Sounding Distance [s] | 2.5 |
| Trapez Gate Time 1 [s] | 1e-5 |
| Trapez Gate Time 2 [s] | 1e-4 |
| Trapez Gate Time 3 [s] | 1e-3 |
| Trapez Width 1 [s] | 5 |
| Trapez Width 2 [s] | 8 |
| Trapez Width 3 [s] | 24 |
| Trapez Spike Factor | 25 |
| Trapez Min. No. Gates [%] | 25 |
| Trapez Min. No. Gates per sound. | 7 |
| Trapez Sync. location of sound. | ON |
| Trapez Require left/right sound. | ON |
| Minimum allowed Tx altitude [m]. | 5.0 |
| Maximum allowed Tx altitude [m]. | 999.0 |

OK Cancel Help

*Figure 11. The Data processor settings, bottom part.*

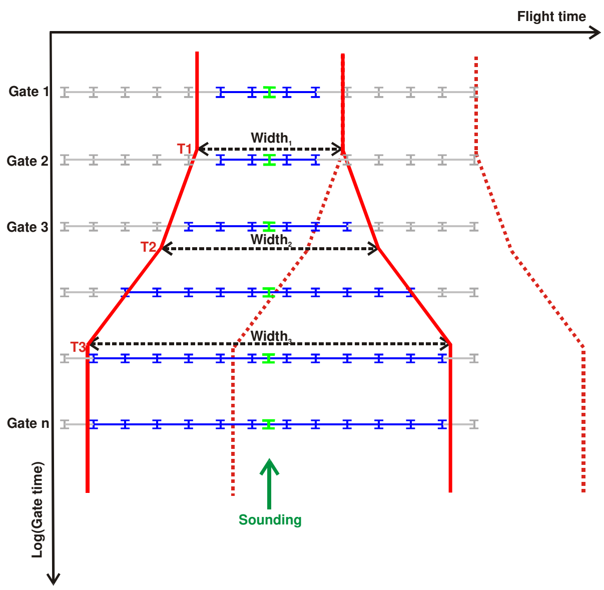



*Figure 12. Principle sketch of trapezoidal filter averaging: The averaging core for the sounding is shown in red, thereby creating an averaged sounding. Subsequently, the trapezium is moved, and another average is calculated*

| Parameter | Comment |
|---|---|
| Trapez Filter | Always On, Off is included for compatibility reasons for very old data. |
| Trapez Sounding Distance [s] | Sets the distance in time between soundings. |
| Trapez Gate Time 1 [s] | Sets the time of Trapez Width 1 |
| Trapez Gate Time 2 [s] | Sets the time of Trapez Width 2 |
| Trapez Gate Time 3 [s] | Sets the time of Trapez Width 3 |
| Trapez Width 1 [s] | Sets the width of the filter at Trapez Gate Time 1 |
| Trapez Width 2 [s] | Sets the width of the filter at Trapez Gate Time 2 |
| Trapez Width 3 [s] | Sets the width of the filter at Trapez Gate Time 3 |
| Trapez Spike Factor | Median filtering of the data. E.g. Spike Factor = 20 removes the upper and lower 10% of the data within the average width for each gate |
| Trapez Min. No. Gates [%] | Minimum number of possible gates in the averaging interval that must be in use for an average sounding to be created. |
| Trapez Min. No Gates per Sound. | If less than Trapez Min. No. Gates per Sounding are in use after the filtering of the average data, the sounding is removed. |
| Trapez Sync. location of sound. | Synchronizes the location/time of the sounding from the different software channels if ON (recommend). |
| Trapez Require left/right sound. | If set to On, raw date are required to both left and right side of the sounding time within the average interval for an average data point to be created. Off makes a more densely sounding/model sampling/averaging possible without getting "holes" in the sounding array. |

*Table 5: Averaging / stacking parameters*

The choice of averaging filter width is a trade-off between the desire to achieve usable low-noise data at late time and to obtain maximum lateral resolution. The averaging filter width should therefore be minimised as much as possible to achieve usable data. A large averaging filter width improves the signal-to-noise ratio, particularly for the last part of the data curve which is close to the background noise level. A large averaging filter width may therefore be an advantage if you are handling noisy data or the target is very deep. A limited averaging filter width is preferable where the signal-to-noise ratio is good and in situations where lateral resolution is a priority. In addition to the averaging filter width, the noise level is a function of the flight altitude, the transmitter moment and the resistivity in the survey area. A high resistivity will e.g. result in a lower signal level. Normally the same averaging setup is applied within a survey area.

## 5.5 Hints and tips

- Note the hierarchy of the processors: Automatic processing of altitude data, for example, demands that the voltage data processing is rerun, thereby overwriting any manual processing. The opposite is, however, not the case so it is possible to e.g. keep automatic and manual processing of altitude data even though the voltage data processor is run afterwards.
- Try ticking both the **Sky** Node and the corresponding Processing Nodes and use the **Zoom to Layer** function, which is accessible via the right-click menu on the **GIS Map** window. This can be used to check the success of the GPS data processing by ensuring that no outliers are present
- If you have trouble detecting which filter is culling the voltage data, try turning them all off and then on one at a time.
- You can save and load Processor settings for each processor in the settings list windows
- If all voltage data are culled when using the **Sign Filter,** it might suggest the data have been recorded with reversed sign, and the sign needs to be flipped.
- Processing is by default deactivated when the workspace is closed. It can also be deactivated manually via the right-click menu of the processing node.
- Minor edits to the geometry file can be applied to the data set via the Re-apply New Geometry function, which is available via the right-click menu of the Processing Node. Depending on the parameters changed, it may be necessary to rerun the automatic processing afterwards.

# 6. MANUAL PROCESSING

This chapter gives a description of the manual (user-made) processing of SkyTEM data, which is the next step after the automatic processing. It involves inspection of and user-made corrections to the data set. Right-clicking on the Processing Node and selecting **Plot Data** opens the **SkyTEM Edit Form**, as seen in figure 10. This form is relatively comprehensive and section 6.2 will describe the various functions of it as well as the principles of doing a manual SkyTEM processing.

## 6.1 Suggested workflow

The following is a suggested workflow for the manual processing and QC of SkyTEM data, assuming that the automatic processing has been applied:

1. Make the necessary corrections to the altitude processing
2. Plot **Raw**, **Average** and **Positions** series for one software channel in the **SkyTEM Edit Form** plot window. Start with the high moment.
3. Find and remove coupled data in the Raw-data series using the **SkyTEM Edit Form** plot window and **Sounding Plots**. Go through the entire data set using a buffer size of 4-5 minutes and remember to press **Update Edits** when finished.
4. Use the **Position** series to select and view averaged soundings in **Sounding Plots**. Typically, it is possible to show 2-5 soundings without losing overview.
5. If needed, add extra STD to noise-influenced (but still usable) average data points and remove very noise-filled data points. The program automatically calculated reasonable data uncertainties based on the data stack. In some cases, manual adjustments are needed.
6. Repeat steps 2 - 6 for remaining software channels.
7. Run a provisional smooth LCI inversion and use this to QC the processing.

Remember to s**ave** the processing to the database at regular intervals.

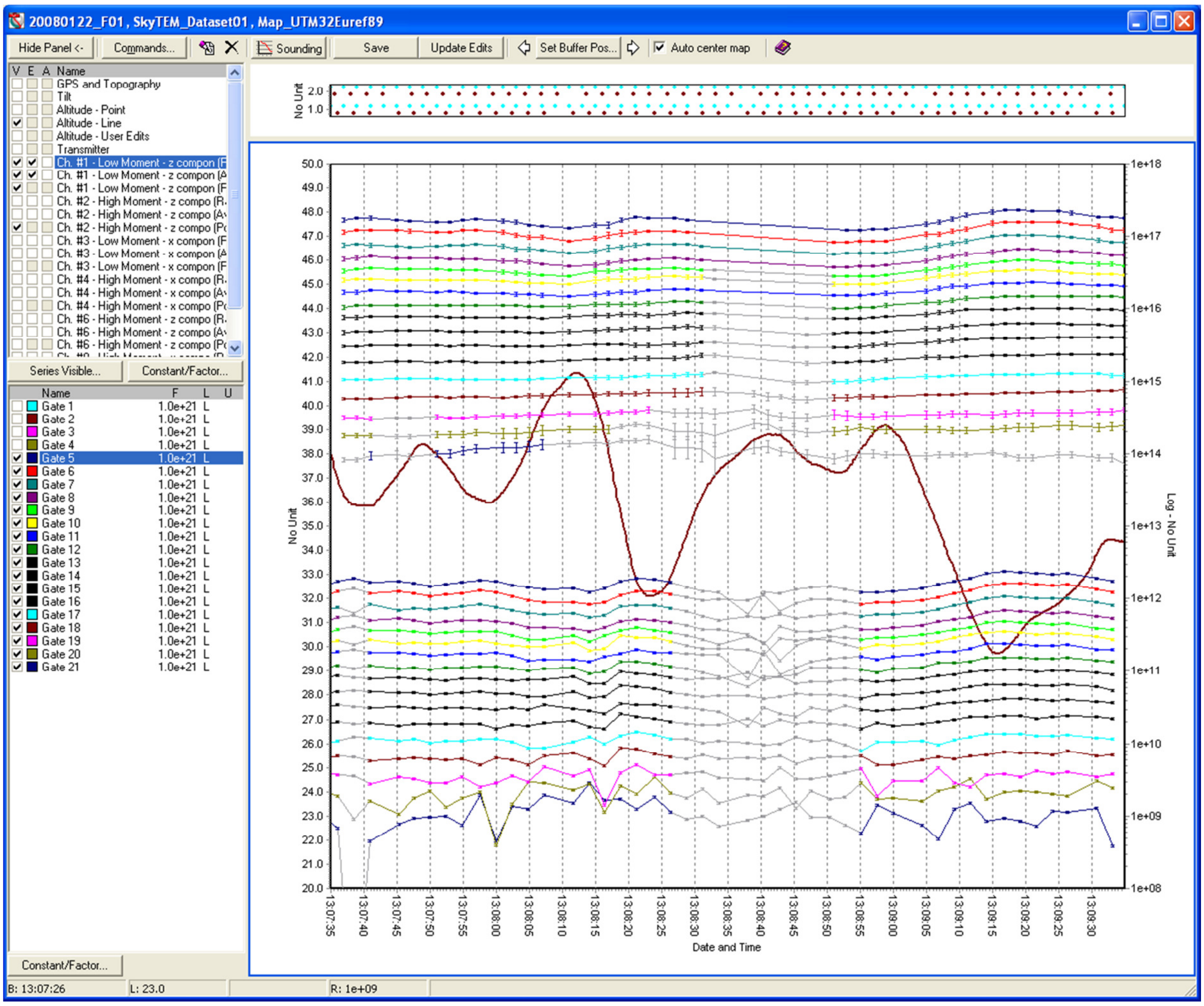



*Figure 13. The* **SkyTEM Edit Form***, which is the basis of evaluation and manual processing of SkyTEM data.*

## 6.2 The SkyTEM Edit Form

The main window in this form is the plot window in which different data series (xy-series) are displayed. The y-axis is without dimensions in the sense that it shows data values on either a logarithmic or a linear scale. Data can, however, be shifted along the y-axis (display only!) making it possible to view more than one otherwise overlapping data series at a time (e.g. **Raw** and **Average** series).

The dimension of the y-axis changes to match the type of data currently displayed while the x-axis shows the time stamp. Two y-axes will automatically appear if e.g. altitude and voltage data are shown simultaneously as these are displayed on linear and logarithmic scales, respectively.

The upper plot window is used to display the **Positions** series. This series shows the position on the x-axis of raw and averaged soundings and may be used to select soundings and e.g. display them in sounding plots (see below).

When the mouse cursor is moved around the plot window, the geographic position of the current data is shown on the **GIS Map** as a red dot to support the processing.

The left side of the plot window shows a number of series and subseries which can be selected and displayed. It is possible to alter the properties of the series:

- **V**: Series are visible.
- **E**: Series are editable.
- **A**: Both visible and invisible series can be selected and toggled off. Use the option with care.

Not all properties are available for all series.

Pressing the **Hide Panel** button can hide the series/subseries list, and make more room for the plot windows.

The **Display** button appears when the edit panel has been hidden, pressing this one makes the edit panel reappear.

The **Commands** button offers the possibility to **Synchronize deleted soundings between channels**, e.g. using the manually disabled soundings from software channel 1 to disable the corresponding soundings of software channel 2. Furthermore it is possible to **Delete soundings with flight height**, i.e. automatically disable soundings when flight height is above e.g. 50 m. By selecting **Display Properties** you can make various edits to the way series are displayed while selecting **Sounding List** brings up a list window of all soundings.

The **Series Visible** and **Constant/Factor** buttons provide two quick ways to edit the display status of xy-series. With the former you can easily set the visibility status of multiple series to on/off and with the latter you can shift data series along the y-axis (visual appearance only). Please note that there are two **Constant/Factor** buttons, one below the series list and one below the subseries list (in the bottom of the **SkyTEM Edit Form**). The former changes the display status of all subseries belonging to the highlighted series while the latter changes the display of the highlighted subseries only. Example: When the series "**Ch#1 – Low Moment...**" is highlighted (as seen below in figure 10), the display of all subseries – in this case "**Gate 1**" to "**Gate 21**" - is changed by pressing the upper **Con-**

**stant/Factor** button, whereas only the display of the highlighted "Gate 5" series is changed when using the lower **Constant/Factor** button.

At any given time it is possible to **Save** the processing at its current stage to the database.

Ticking the **Auto center map** button in the menu bar of the **SkyTEM Edit Form** makes the **GIS Map** automatically centre on the helicopter position, i.e. as the user proceeds through the data, the **GIS Map** automatically follows the updated helicopter position.

The **Select SkyTEM** tool, the green arrow available in the **GIS Tools** bar, centers the plot window on a selected data point. This tool allows you to click on a GPS point on the **GIS Map** (tick the Processing Node), and the **SkyTEM Edit Form** will update to the location of the data (the form must be open).

**Buffers – navigating in the SkyTEM Edit Form**

As the processing requires significant memory, only a certain amount of data is read into the memory and displayed at a time, e.g. two minutes of data as seen in figure 10. This is called the buffer. It is possible to move this buffer by pressing the Back/Forward arrows on the menu bar. Pressing the **Set Buffer Pos...** button opens up the **Buffer Size and Position** window, as seen in Figure 14., which controls the buffer properties. The plot window shows the distribution of different data types and the current buffer zone (red block):

- **Buffer Start Time**: The start time of the current buffer
- **Buffer size in minutes**: The length of the buffer
- **Buffer Overlap**: Defines the overlap when the buffer is moved.

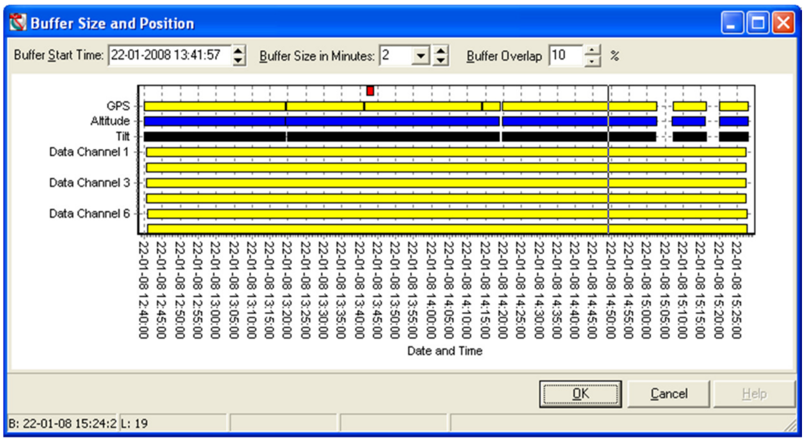



*Figure 14. The* **Buffer Size and Position** *window used to navigate through data in a Processing Node.*

### 6.3 Altitude processing

Manual corrections to the automatic altitude processing may be needed, typically dense forested areas. The altitude is included as an inversion parameter with the recorded altitude as a prior value, and a slightly incorrect input altitude will therefore be corrected during the inversion.

**Altitude – Point** and **Altitude - Line** show the same series but as points and a line respectively. Subseries are (# denotes device number):

- **Tx**: Tilt corrected altitude data after automatic processing. Calculated as the mean of **# Pass 2**.
- **Tx Edited**: The final transmitter altitude data including tilt correction and user edits. Furthermore, the altitude has been corrected for the position of the laser not being in the centre of the transmitter.
- **Rx Edited**: Final receiver altitude data including tilt correction and user edits. It is calculated from **Tx Edited** and the distance between the transmitter and receiver (from the geo file).
- **# Raw Pass 1**: Remaining altitude data after the first pass of polynomial fits. Tilt corrected.
- **# Pass 2**: Tilt corrected altitude data after the second pass of polynomial fits.
- **# Raw**: Raw tilt corrected altitude data before polynomial fits.
- **Altitude - User Edits** contains user created series, i.e. edits made to the altitude processing.

Please note that **Tx**, **Tx Edited** and **Rx Edited** series are corrected for the position of the laser not being in the middle of the transmitter. When the frame tilts, it results in an altitude offset between these and other altitude series where this correction is not included.

**How to make altitude processing corrections**
Follow these steps to make edits:

1. Plot the **Tx Edited**, **1 Raw** and **2 Raw** series of the **Altitude - Point** collection.
2. Make the **Altitude - User Edits** series visible.
3. Find a position where corrections are needed.
4. Create a new **Altitude - User Edits** subseries by pressing the **Add New Series to Selected Collection** button on the top menu of the **SkyTEM Edit Form**.
5. Highlight the subseries that will contain the edits.
6. Draw a polyline on the plot window in the **SkyTEM Edit Form** using the **Draw Series on Chart** tool, which is accessible via the **Chart Tools** bar. This polyline replaces the original Tx/Rx series in the time interval in question.
7. Press **Update Edits** to see the effect immediately in the **Tx Edited** series.

Repeat step 3-7 where correction is needed.

An **Altitude - User Edits** series can be deleted by pressing the **Delete Selected Series** button in the menu bar, in which case the Tx/Rx series are used again.

Changes made to the Rx/Tx series are applied by using the **Update Edits** button of the menu bar.

## 6.4 Tilt processing

No manual corrections can be added to the automatic tilt processing. You may need to cull data if the tilt is too large. The subseries for Tilts on the SkyTEM edit form in Figure 13 are (# denotes device number):

- **Cor Factor**: The factor used in the correction of voltage data. This value should always be >1.
- **Ave x**: The mean angle in the x direction.
- **Ave y**: The mean angle in the y direction.
- **# Fit x**: Processed tilt data in the x direction.
- **# Fit y**: Processed tilt data in the y direction.
- **# Raw x**: Raw tilt data in the x direction.
- **# Raw y**: Raw tilt data in the y direction.

## 6.5 Voltage data processing

Voltage data processing includes removal of coupled and noisy data and adding an uncertainty to the latter. The series are **Raw** (raw data series), **Average** (averaged data series) and **Positions**. Sub series for the two former are the gate values while sub series for the latter are position dots for **Raw** and **Average** soundings.

Data curves can be shown in **Sounding Plots** (see Figure 15) which are available from the **SkyTEM Edit Form** menu bar. These show either raw or averaged data as either dB/dt or rhoa. Multiple sounding plots may be opened at the same time. Soundings can be visualized and processed directly in the sounding plot by selecting a number of "dots" in the Positions series plot. Data points may be selected, disabled/enabled, and noise may be added using this method. The series must be **Editable** (tick **E**) to make edits.

Selector tools are available via the **Chart Tools** bar or the right-click menu of either the plot windows of the **SkyTEM Edit Form** or the **Sounding-Plots.**

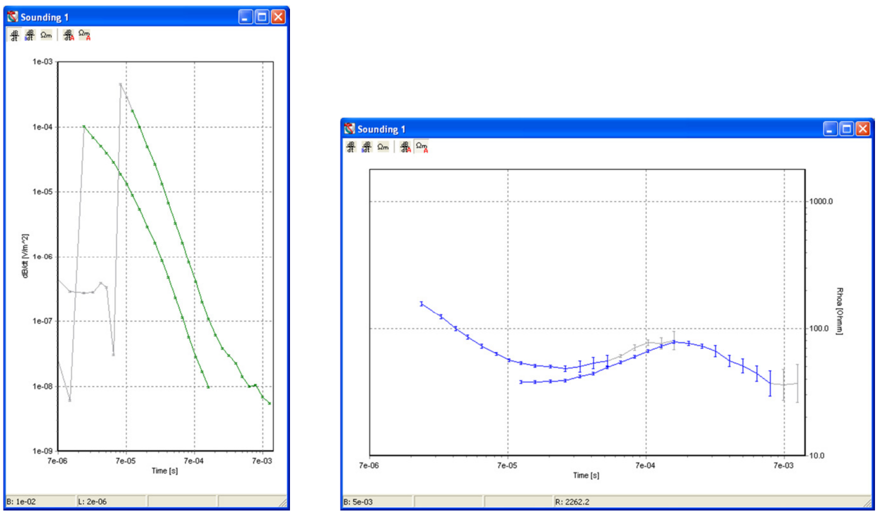



*Figure 15. Sounding Plots in Rhoa (a) and dB/dt (b). These are very helpful in the evaluation of data and can be used to make manual processing of the SkyTEM data.*

For a description of noise contamination of electromagnetic soundings, see /4/.

### Removal of coupled data

The first step in the processing is to remove coupled data from the raw data, the **Raw** data series. It is vital to do this on raw data as couplings must be removed before the final averaging of data. Edits can then be made using the **SkyTEM Edit Form** plot window or the **Sounding Plots**. Proper GIS themes (roads, railroads, pipe lines, power lines etc.) are very useful in this step as they will often reveal the reason for the coupling. The easiest way to do this is to use the main plot window to get an overview of the data, thereby spotting and removing major distortions in data. These will be seen as "jumping" of data curves or intervals where the spread between gates increases or decreases.

After this initial step the **Sounding Plots** can be opened and specific data curves inspected to get a detailed view and to remove distorted data points.

Note that altitude variations and signal variations are linked. It is therefore advisable to show altitude data along with the voltage data during processing.

To see the effect that the removal of a coupling in the raw data has on the **Average** series, press the **Update Edits** button.

**Noise processing**

Noise processing must be performed on averaged data, the **Average** series. It is therefore vital that couplings are removed from the raw data stacks prior to this.

Noise processing is possible either on the **SkyTEM edit form** or by using **Sounding Plots** where data points can be removed, or additional uncertainty, STD, can be added to the data. The program automatically calculates an uncertainty for each data point. The STD is a combination of three factors:

- The STD of the stack, $STD_{stack}$
- The uniform STD, which is stated in the geo-file, $STD_{uni}$
- The user defined STD, $STD_{user}$

Only the latter can be changed by the user at this stage. This is done by selecting data points and pressing the **Toggle STD** button of the Aarhus Workbench main menu bar.

The total data STD is given as: $STD_{tot} = \left(STD_{uni}^2 + STD_{stack}^2 + STD_{user}^2\right)^{1/2}$

## 6.6 Provisional Inversion

It is highly recommended that the manual processing is followed by a first run of inversions (provisional inversions), using smooth models combined with the 1-D Laterally Constrained Inversion scheme

(GeoFysikSamarbejdet, 2007), before making final inversions using the Spatially Constrained Inversion scheme (see chapter 8).

The provisional inversions are used as a QC of the processing and to obtain further knowledge of the geological structures of the survey area, thereby allowing a better first shot at the SCI setup.

The LCI inversion is initiated using the *Inversion Settings* form, which is accessible from the right-click menu of the *processing node* and is the control center used in the setup of the inversion job. Settings can be saved to and loaded from inv files.

LCI inversion as a tool for QC makes it possible to delete unfitted data points or even entire soundings showing e.g. signs of coupling.

### 6.7 Hints and tips

- Due to the automatic processor hierarchy, doing an automatic processing of altitude data by default overwrites any manual processing of the voltage data, whereas the reverse is not the case. Therefore it is advisable to begin by processing altitude data and concentrate on voltage data afterwards
- Various tools and display properties are available via the right-click menu on plots, collections or series
- Use the **Constant/Factor** function to shift the **Raw** and **Average** series along the y-axis so they can be displayed simultaneously
- Making **Altitude - User Edits** subseries invisible after edits ensures that no further edits can be made to them
- Data averaging increases the signal-to-noise ratio, so do not make noise processing of voltage data on the Raw series. Furthermore, removing numerous Raw data point often prevents the noise from stacking up
- During voltage processing, it is advisable to process one software channel at a time, e.g. to concentrate on Super low Moment and show **Raw** and **Average** data for this along with the altitude. Afterwards the results from the other software channels can be compared to the already processed software channel.
- Do not show more data than you can handle in the **SkyTEM Edit Form**, typically no more than 2-3 minutes of voltage data, whereas e.g. 5 minutes of altitude data are usually ok
- When doing manual processing of voltage data, it may be useful to plot one gate of previously processed software channels. This helps you identify places where data have been removed from this software channel. Use the first effective gate and make the series non-editable to avoid removal of data from it by mistake
- Useful keyboard shortcuts during processing are shown in Table 6.

| Hot key | Action |
| --- | --- |
| Ctr+Alt+left/right arrow | Moves buffer |
| Ctrl+Alt+i | Updates Edits |
| Ctrl+Alt+u | Opens Buffer Size and Position window |
| Ctrl+s | Saves processing to GERDA |
| Alt+1 | Add 5% User STD |
| Alt+2 | Add 10% User STD |
| Alt+Q or ALT + "-" | Disables selected data points |
| Alt+A or ALT + "+" | Enables selected data points |

*Table 6: Useful keyboard shortcuts in the processing of SkyTEM data.*

# 7. SCI INVERSION

The SCI is a robust methodology for quasi-3D modeling of geoelectrical and EM data (e.g., SkyTEM) of varying spatial density (GeoFysikSamarbejdet, 2008), (Part A: Piecewise 1D Laterally Constrained Inversion of resistivity data, 2003). The SCI methodology is based on a 1D forward solution using the em1dinv inversion code /8/. Both data and constraints are part of the inversion, which therefore results in output models that balance between the data and the constraints. Model parameters with minor influence on the data will be controlled by the constraints, and vice versa.

The SCI-inversion scheme uses lateral constraints thereby allowing for more stable inversions and a better resolution of medium to poorly resolved model parameters. The horizontal constraint connections are determined by a Delaunay triangulation of the data set. The horizontal constraints are scaled by distance so that soundings far apart are more loosely constrained than those close together. The effective constraint between two models (**C**) with **ΔGPS** between them is given by this scaling function:

$$C = 1 + (C_{opt} - 1) \cdot \left(\frac{\Delta GPS}{Dist_{ref}}\right)^n$$

$\mathbf{C_{opt}}$ is the user stated constraint for the nominal sounding distance $\mathbf{Dist_{ref}}$ , and $\boldsymbol{n}$ is the scaling power e.g. $\boldsymbol{n}$=1 is a linear scaling of the constraints with the distance, $\boldsymbol{n}$=½ square root scaling. $\boldsymbol{n}$ thereby controls the balance between constraints in line and constraints across flight lines. A smaller $\boldsymbol{n}$ results in relatively stronger constraints across flight lines.

Note that constraints do not decrease if soundings are closer than the specified reference distance.

The constraints can be compared to a rubber band with certain strength. A smaller constraint value is equivalent to a less elastic rubber band. The rubber band does not have a specific maximum length, but as you get further away from the starting point, it becomes less elastic. Constraint values are given as factors, i.e. a factor of 1.1 means that the parameter can vary between the starting value divided or multiplied by 1.1. Setting a constraint factor to a value of 99 is equivalent to disabling it.

In order to perform the SCI in a CPU-efficient manner, large data sets are divided into slightly overlapping subsets (sections). The SCI-cells are inverted in parallel using all available CPUs. To ensure model continuity at the section edges, a weighted average of the models in overlapping regions is calculated. The average models are used as a-priori model for a second inversion run.

Updated recommended SCI-inversion settings are found in "Guideline and standards for SkyTEM Measurements, processing, and inversion, appendix 5" (HGG, 2010).

## 7.1 Setting up an SCI inversion

To initialize a SCI inversion right-click on a *Sky*- or *Map* node and select **New SCI**, this brings up the SCI Setup Wizard, which is a four-step guide to setting up an SCI inversion. The different steps will be described below.

## 7.2 Source Selection

Step one in the **SCI Setup Wizard is Source Selection** (see Figure 16). Data sets (sources) can be added to or removed from the SCI-inversion. It is possible to include more data sets in an SCI-inversion if they are present in the workspace. To the right of the form, lateral constraints, prior STD, etc. for the altitudes must be specified. **Bias inversion** and **Pitch** setting are only used / needed in special cases.

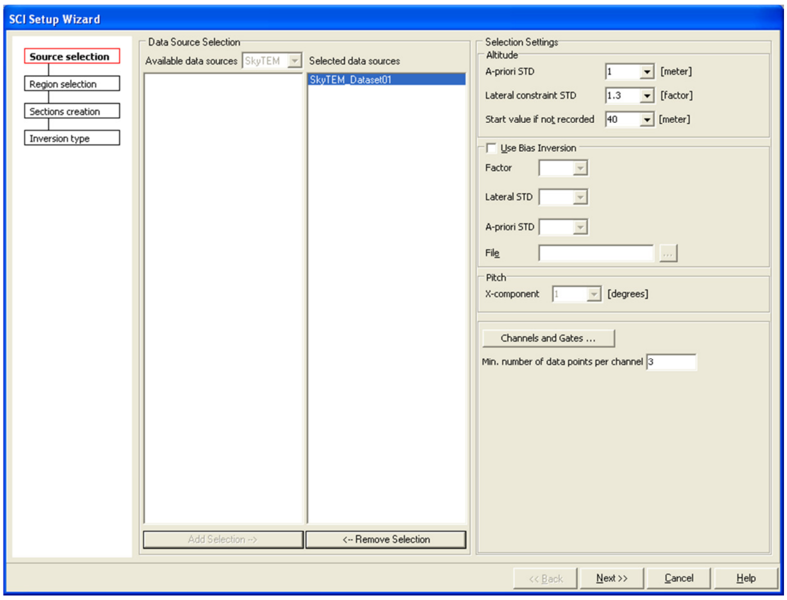



*Figure 16. The SCI Source Selection window where different data sets can be combined in an SCI inversion, and different parameters concerning the data can be set.*

**Channels and Gates** button opens the form in Figure 17. Here you must specify which channels to include in the inversion – typically a Low moment z-component and a High moment z-component. It is also possible to exclude specific gates from the inversion if not already excluded during data import or processing.

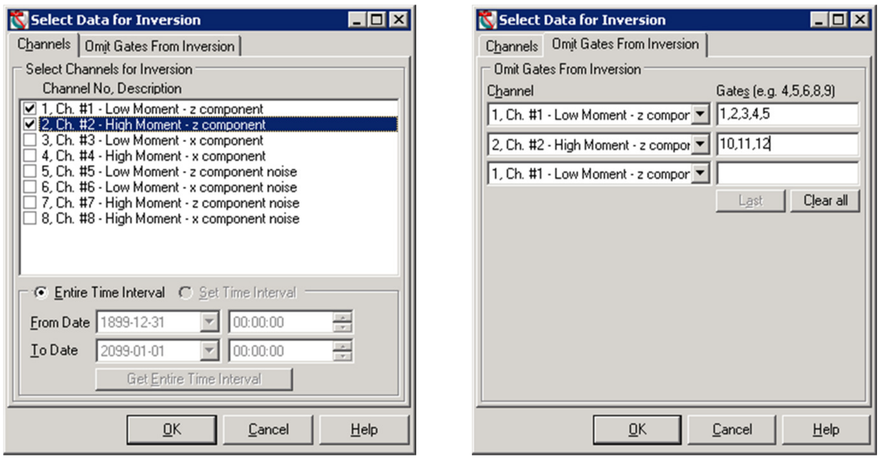



*Figure 17: Channels and gate for inversion.*

## 7.3 Region Selection

The second step in the SCI-wizard is **Region Selection**. In this step it is possible to select a smaller square region for inversion (see Figure 18).

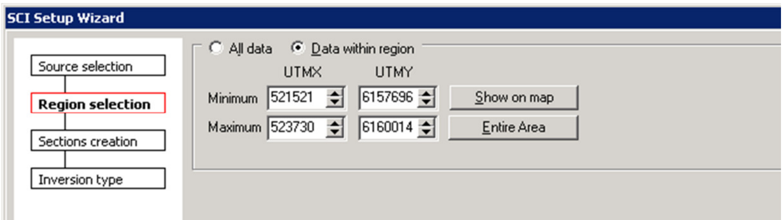



*Figure 18: SCI region selection.*

## 7.4 Section creation

Step three of the *SCI Setup Wizard* is setting up the SCI sections (see figure 14). Data are divided into sections with an **Approx. size**, and **Min. size**. The histogram shows the section size distribution. Press the *New* button to generate a new section setup with the stated parameters.

To avoid large sections the **Minimum size** should be set to approximate ¾ of **Approx. size**.

Use the **Edit starting point** options to have exactly the same sectioning form a previous SCI-setup of the dataset. The **starting point** seed of an SCI-job is listed under properties for an SCI-node I the **workspace manager**.

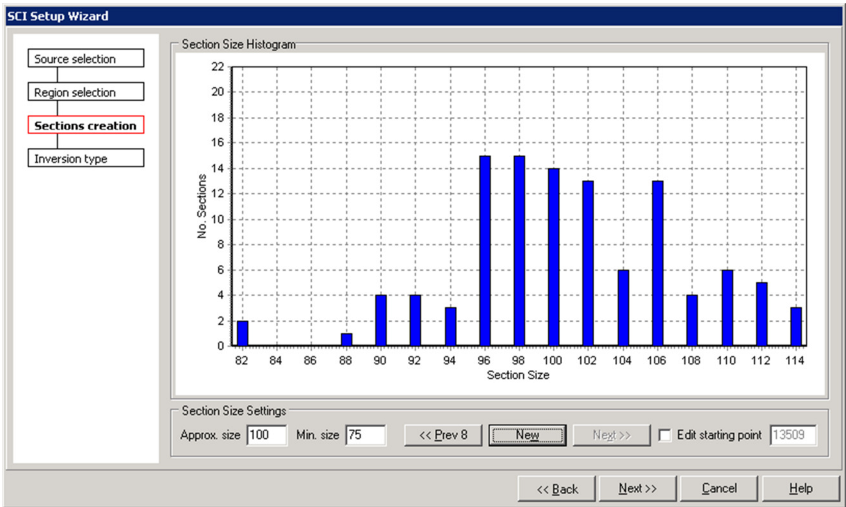



*Figure 19. SCI Section creation window, where the sections of the SCI inversion are created.*

## 7.5 Inversion Type

The fourth and final step of the *SCI Setup Wizard* is *Inversion Type* (see figure 15), where starting model, constraints and various other inversion parameters must be stated.

The center part of the form holds three tab sheets (see Figure 20 to Figure 22) with start **model**, **constraints** setup and **inversion Settings**.

## Model

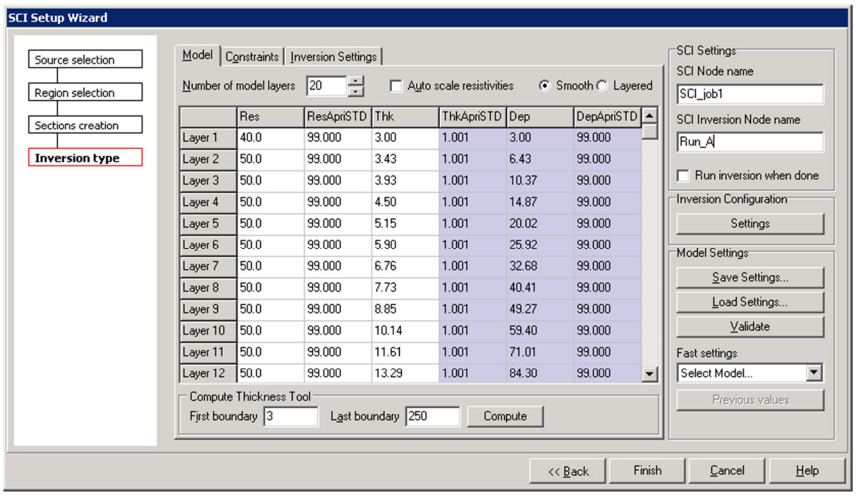



*Figure 20. The* SCI Inversion type *window, Model tab sheet.*

The 1D-model type can be either **Smooth** or **Layered** (Shape layer boundaries).

Starting model parameters can be specified in terms of layer resistivities (**Res.**) and thicknesses (**Thk.**) with optional a-priori constraints (**ResAprioSTD, ...**). If Auto **scale Resistivities** is ticked, the start resistivities for each model are calculated based on data and the flight altitude.

The **Compute Thickness Tool** makes a logarithmic distribution of the layer boundaries from the user input.

## Constraints

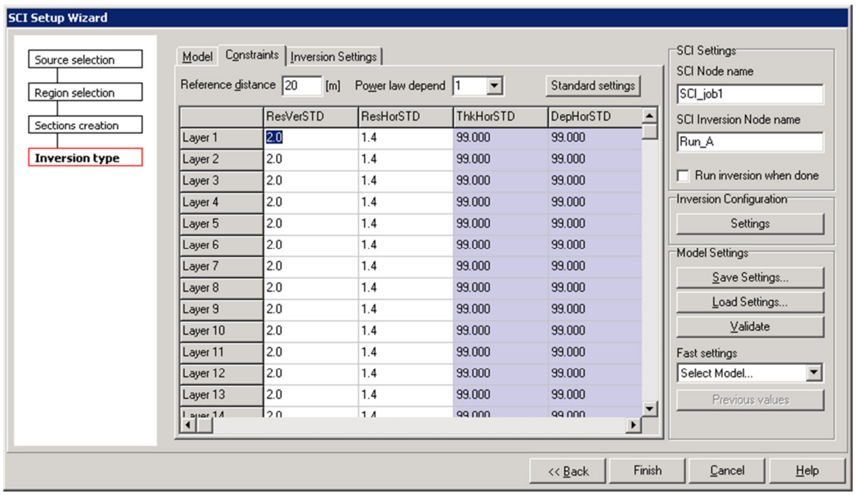



*Figure 21. The SCI Inversion type window, Constraints tab sheet*

Vertical constraints (**ResVerSTD**) and horizontal constraints (**#HorSTD**) are specified in the constraints tab sheet (Figure 21). Horizontal constraints are scaled by distance using the given **Reference distance** and **power law depend**.

## Inversion settings

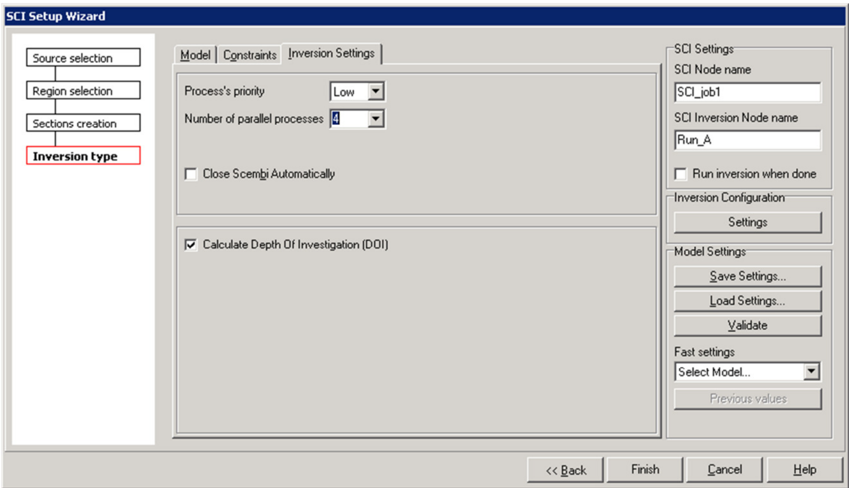



*Figure 22. The SCI Inversion type window, Inversion Settings tab sheet.*

In the Inversion tab sheet, you find settings (Figure 22) of the computation process. Remember to set the **Number of parallel processes** according to current computer power. The number can be changed during inversion. Check the **Calculate Depth of Investigation** box to include a depth of Investigation estimate from the inversion.

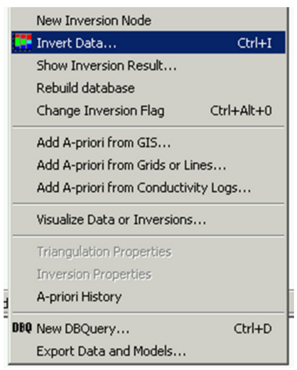
**Right side panel**

- State the name of the main SCI node and corresponding **SCI Inversion Node**.
- Ticking the **Run Inversion when done** will start the inversion right after the inversion setup has been written to the database, and no further editing of start models and prior constraints is possible. If left un-ticked the inversion process must be started from the right-click menu of the inversion node. Additional editing of start models and prior constraints before inversion, see section 7.7.
- **Inversion Configuration/Settings** contains additional advanced inversion configuration settings.
- **Model Settings(**inversion setup) can be saved/loaded from a file.

When finished, press the *Finish* button after which the Aarhus Workbench will copy all necessary data into two newly created databases corresponding to the SCI node and the SCI inversion node. These databases are by default stored in ...\workspacedir\sci\SCINodeName.

An SCI-job creates four nodes as shown in Figure 23. The main SCI-node holds the model positions. The sub-node xxx_Sec displays the SCI- section while the xxx_Cons displays the constraint connections from the Delany triangulation.

From the inversion node right click menu, the SCI-inversion can be started or the inversion results can be inspected.



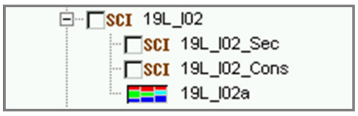



*Figure 23. Set of SCI-node in the workspace manager (a). SCI-node right click menu (b)*

### 7.6 Scembi

The inversion process is controlled by an Aarhus Workbench application called **Scembi,** see Figure 24.

The SCI-Inversion sections (jobs) are started continuously; when one job is finished, the result is written back to the database, and the next job is started. Detailed information of the computation process is displayed in the **Message Log** window.

The status bar indicates whether problems occur during inversion: green status bar indicates that an inversion finished without encountering problems, yellow status bar indicates that the inversion is still running, and red status bars indicates errors.

**Scembi** requires constant access to the database. However, it does not require that the Aarhus Workbench is running. This makes it possible to split up the inversion and run multiple instances of **Scembi** simultaneously and even on more than one computer as long as there is access to the database.

The **Pause** button stops **Scembi** from starting new inversion jobs. Already running jobs will be finished, but results will not be written in the database until *Resume* is pressed.

The Process Priority and **Number of CPUs** drop-down boxes control the window priority of the following inversion jobs and the number of parallel processes, respectively. Already running jobs will continue on the same priority. Reducing the number of parallel processes will take effect when an inversion job has finished.

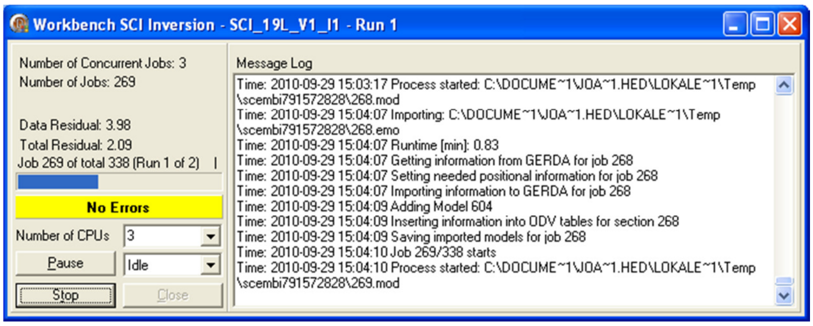



*Figure 24. The SCEMBI application controlling the SCI inversions.*

During the inversion, intensive database operations are performed, and the database is automatically rebuilt. This may cause the SCEMBI log window to not respond for a while (sometimes for hours in case of large datasets) – be patient, and do not stop the SCEMBI application.

## 7.7 Adding a-priori to SCI inversions

A-priori information can be added to SCI inversions in the form of grids/lines, conductivity logs or user-defined model definitions.

A-priori information can only be added to SCI Inversion Nodes that have not been inverted. New SCI Inversion nodes can be created

- by using the **SCI Setup Wizard** (see section 7.1) or from the right-click menu of a main SCI node. In both cases the overall starting model in terms of layer parameters (layer resistivity's and thicknesses) is uniform.
- from the right-click menu of a previously inverted SCI Inversion Node. In this case the starting models will be the inversion results from the inversion node.

To add a-priori information, right-click on the SCI Inversion node and select **Add A-priori from GIS**, **Add A-priori from Grids or Lines** or **Add A-priori from Conductivity Logs**.

To keep track of prior and start model edits, view the **A-Priori History** from the right-click menu of the SCI Inversion node.

The following will give an introduction to the three prior/start model edit options mentioned above.

### Adding a-priori from GIS

It is possible to customize starting model and prior constraints for a selected model on the GIS-map.

- Display model positions from the main SCI inversion node on the GIS map.
- Select models for editing with the different GIS select tools. For multi selections, hold the Ctrl button.
- Select **Add A-priori from GIS** from the right-click menu of an SCI Inversion node you want to edit. This makes the **Model A-priori Editor** form, shown in Figure 25, appear.
- You can add a-priori to resistivity's and depths. If you only want to change the start value of the model parameter, set **A-priori STD** = 99.
- Press **OK** to close the window and apply the edits to the node. Repeat steps 1 - 5 for more edits.
- Select **Invert Data** from the right-click menu of the SCI Inversion node to run the inversion with the added prior and start model edits.

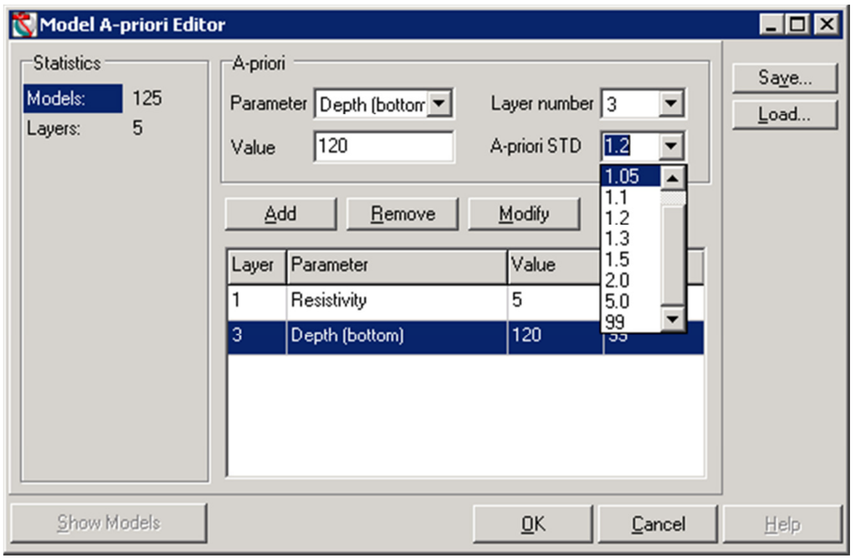



*Figure 25. The* Model A-priori Editor *where a-priori information can be added to layer parameters of a number of models selected on the GIS map.*

### Adding a-priori from Grids or Lines

Adding a-priori information from grids or lines is a way of using e.g. geological surface or seismic profile information in the inversion setup.

- Select **Add A-priori from Grids or Lines from the** right-click menu of an SCI Inversion node. This opens the form in Figure 26.
- Select whether to use a grid or a profile (**line file**) as source, and set the coordinate system of the file. In case of grids only, the models covered by the grid will be affected. In case of line file, only models with in the **search radius** will be affected.

- Select which layer parameter the a-priori information should be applied to, and specify the **A-priori STD**. If **A-priori STD** = 99, only the starting model value will be affected.
- Press the **Settings** button to specify how to deal with inconsistent depths, e.g. cases where depth to layer 3 from top is lower than depth to layer 2 from top.
- Press **OK** to close the window and to apply the specified changes.
- Select **Invert Data** from the right-click menu of the SCI Inversion node to run the Inversion with the added prior and start model edits.

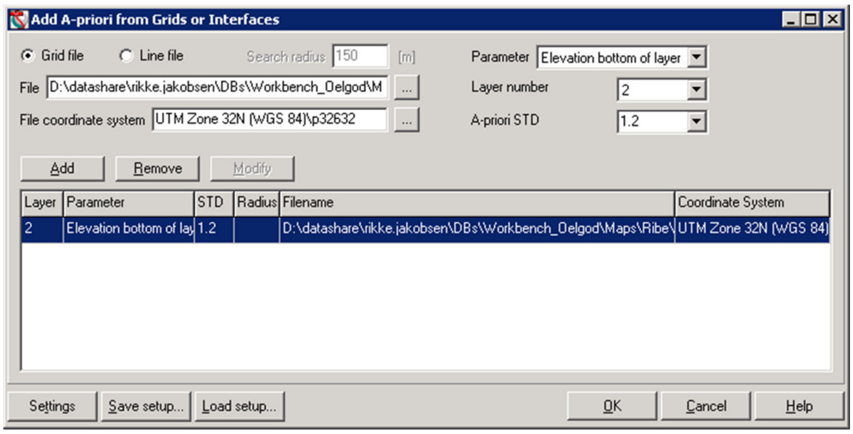



*Figure 26. The* Add A-priori from Grids or Interfaces *window, where a-priori information can be added to layer parameters using information from grid or interface files.*

### Adding a-priori from Conductivity Logs

It is possible to add a-priori information from conductivity logs to the inversion.

Select **Add A-priori from Conductivity Logs** from **the** right-click menu of an SCI Inversion node. This opens the *Add A-priori Conductivity on node* form. shown in Figure 28.

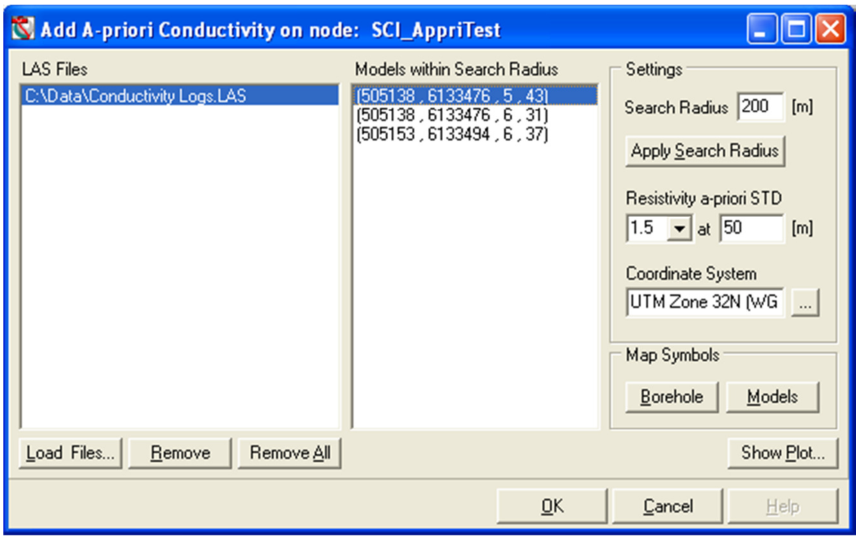



*Figure 27. A-priori from LAS files*

- Conductivity log data are specified in LAS format. To select one or multiple LAS files, press the **Load Files** button and point to the files (use ctrl+click for multiple select). Remember to specify the coordinate system of the LAS files.
- Go to the **Settings** section of the window to set e.g. the search radius. All models within the search radius will be affected by the a-priori information from the conductivity log. Remember to press the **Apply Search Radius** button when the Search Radius has been changed.
- Specify a-priori constraint and reference distance. The stated a-priori STD is applied to the models within the reference distance. The a-priori STD for the models in the interval "**reference distance** to **search radius**" is automatically set looser away from the log. This scaling of the a-priori STD is linear with the distance.
- Press *OK* to close the window and apply the selected a-priori information. Select *Invert Data* from the right-click menu of the SCI Inversion node to run the Inversion.

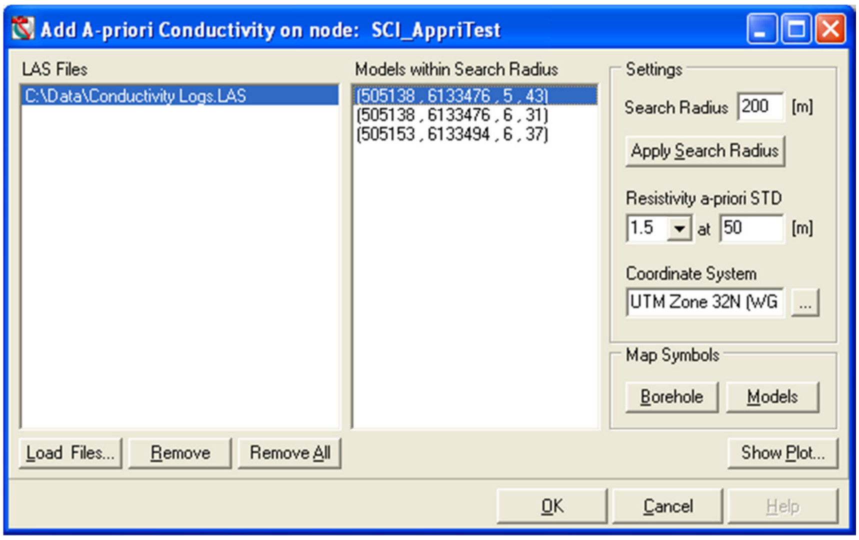



*Figure 28. The Add A-priori Conductivity on node window where a-priori information can be added using information from conductivity logs.*

# 8. LCI INVERSION

This chapter gives a description of the 1D-LCI module which is an integrated part of the Workbench applicable for all data types.
Initiating the inversion is similar to the procedure used for SCI with SkyTEM data and we refer to chapter 7.1 – “Setting up an SCI inversion” for information on how to do this.
The chapter begins by giving a description of the inversion settings, moves on to the running of inversions, the inspection of inversion results, and resubmission of inversions and finally gives a run through of a suggested workflow.
Extra information about different functionalities is often available by accessing the online help (F1).
The horizontal constraints used in the LCI sections are scaled by distance so that soundings far apart are more loosely constrained than those close together. The following power function is used

Where C is the used constraint, $C_{opt}$ is the optimal constraint at a sounding distance of $Dist_{ref}$ and ΔGPS is the actual sounding distance.
Constraints can be thought of as a rubber band with certain strength. A smaller constraint value is equivalent to a less elastic rubber band. The rubber band does not have a specific max length, but as you get further away from the starting point it gets less elastic. Constraint values are given as factors, i.e. a factor of 1.1 means that the parameter can vary between the starting value divided or multiplied by 1.1.
Setting a constraint factor to a value of 99 is equivalent to disabling it.
There are two approaches to setting up an 1D-LCI inversion (Figure 29):
The automatic one mode is not recommended for SkyTEM data and will not be explained here
The full manual approach is giving the user full access to all the handles in the inversion on the model side as well as on the technical inversion side.

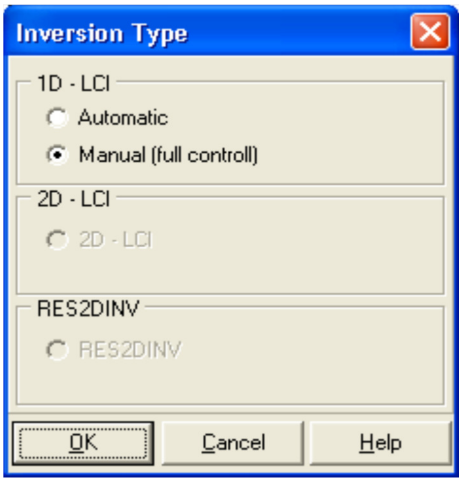



*Figure 29. Choosing the Inversion Type. 2D-LCI and RES2DINV are only for geoelectrical data*

## 8.1 Inversion settings, manual

The **Inversion Settings** form is the control center used in the setup of the inversion job. Settings can be saved to and loaded from inv files. The **Validate** button validates the syntax. **Conf File** opens up the **em1dinv configuration Manager** which is described separately.

A description of the tab sheets of the **Inversion Settings** form and the settings belonging to these will be given below.

Model

The Model tab sheet is seen in Figure 30. Here the starting model in terms of layer parameters and a priori constraints is specified

You can choose between a **Smooth** model setup or a **Layered** model setup using the apropriate radio button. Giving numbers for First layer boundary and Last layer boundary scales the model thicknesses automatically using a log-distribution.

**Constraints**

This tab sheet is concerned with horizontal and vertical constraints (see Figure 31). Horizontal constraints are scaled by distance using a reference distance and power function.

Constraint factors are entered in the tabular section of the form. Vertical and horizontal constraints on resistivities are available along with horizontal constraints on thicknesses and depths.

The default constraints are set with reference to the **Smooth** or **Layered** choice under the model setup.

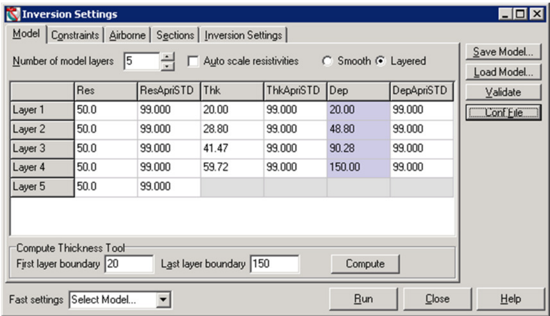



*Figure 30. The Model tab sheet where layer parameters for the starting model are given.*

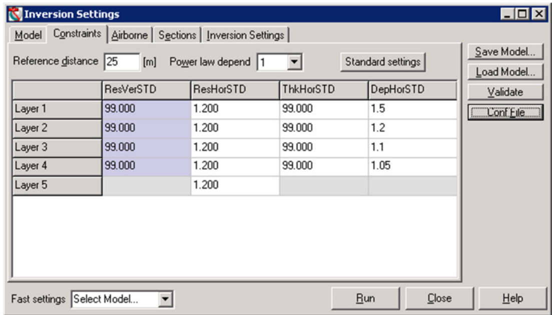



*Figure 31. The Constraints tab sheet. The models in terms of constraints are given here.*

## Airborne

In the Airborne tab sheet, seen in Figure 32, settings concerning tilt and altitude data are entered. Settings are:

**X-tilt a-priori STD:** Defines how much extra uncertainty is added to the tilt parameter from the processing (in degrees) for x component models.

**X contaminated lateral constraint scaling factor**: Scaling factor of horizontal constraints between x- and z-component models, i.e. if a constraint of 1.3 was entered in the **Sections** tab sheet and a scaling factor of 0.2 is used the resulting horizontal constraint between an x- and a z-component model would be 1.3*0.2.

**Use soft channel inversion groups**: E.g. [1,2] results in one model will include booth channel 1 and channel 2 data (low moment, high moment ) if the channels has been synchronies at the data processing stage. If unchecked, low moment and high moment soundings will be assign each a model.

**Bias inversion:** Settings concerning inversion wit adaptive bias correction of early time gate..Concept is not described here – for expert users only.

**Altitude a-priori STD**: The uncertainty of the altitude in meters that goes into the inversion.

**Altitude lateral constraint STD**: The lateral constraint on the altitude between models along the flight lines.

**A-priori altitude if not recorded**: If no altitude I available has been recorded this value will be entered in the inversion for the concerned models.

The two first settings are only in use for SkyTEM x-component models.

### Sections

In **Sections** the model section of the inversion is set up (see ). Settings include:

**Length** controls the maximum length of the section (in number of soundings). A new section is however started if the distance between two neighboring soundings exceeds a certain number.

**Max Sounding Gap** defines when a new section is created.

**Start models from previous section** uses the result of the last finished section as starting model to speed up the inversion.

**Force Continuous Models** ensures continuity across section borders by using the inversion result of the last model before the section boundary as starting model for the first model after the boundary. A priori constraints on model parameters are also applied. These are taken from the parameter analysis of the input model. Use of multiple CPUs is not possible.

### Inversion Settings

This tab sheet holds different settings concerning the actual inversion Figure 33.

**Process Priority**: The windows priority of the inversion code.

**Number of Parallel Processes**: Enables the possibility of running more than one process simultaneously, parallel computing.

**Min number of data points**: Minimum number of data points in the sounding before it is used in the inversion.

**Calculate DOI**: Checking this box will make sure that Depth of Investigation (DOI) is calculated for each model after the inversion job is done. The settings for DOI are controlled in the **Conf File**

## 8.1 Running inversions

The inversion process is controlled by a Workbench application called **Embi** (figure 2.6). When the **Run** button is pressed files are written out to a temporary directory on the computer (This is usually a place like C:\Documents and Settings\user.name\Local Settings\Temp\EMBIInv###\) and **Embi** is started. It also creates an **Inversion Node**.

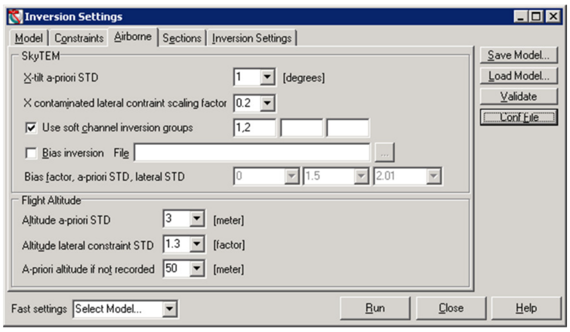



Figure 32. The Airborne tab sheet where settings concerning tilt and altitude parameters are entered for airborne data.

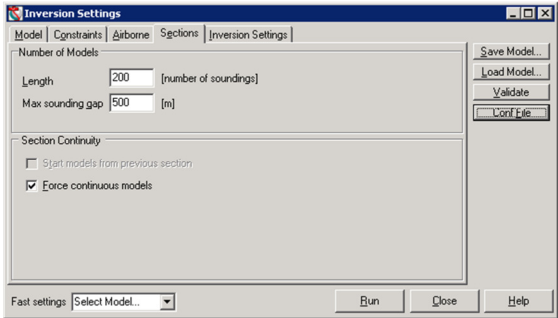



Figure 33. The Sections tab sheet. Here the parameters controlling the model section are given.

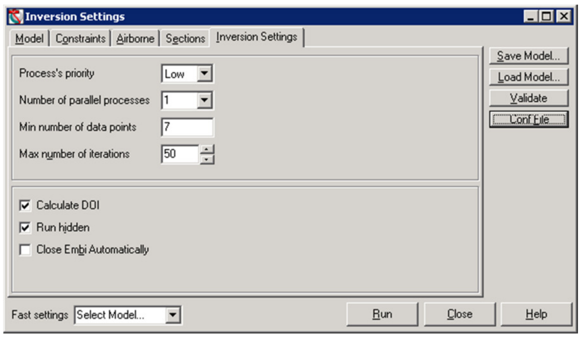



*Figure 34The inversion settings tab sheet where different parameters controlling the inversion process are given.*

**Embi** writes model files based on the settings that were given in the inversion settings and starts inversion jobs by sending commands to the inversion code. Jobs are started continuously; when one inversion job is finished results are written in the database, the next model file is read and the job is started. The inversion jobs are finished when thestatus bar is green. Red status bars indicates errors in the inversion. Temporary files are deleted when **Embi** is closed.

**Embi** requires access to the database at all times. It does however not require that the workbench is running. This makes it possible to split the inversion up and run multiple instances of **Embi** simultaneously and even on more than one computer as long as there is access to the database. If errors occur (e.g. missing access to database, various errors in the inversion routine, etc.) a message will be posted.

The **Pause** button stops **EMBI** from starting new inversion jobs and from writing results in the database until **Resume** is pressed. Already running jobs will however be finished.

The **Process Priority** drop down box controls the window priority of following inversion jobs. Already running jobs will continue on the same priority.

Unwanted inversions can afterwards be deleted via the right-click menu of the **Inversion node**.

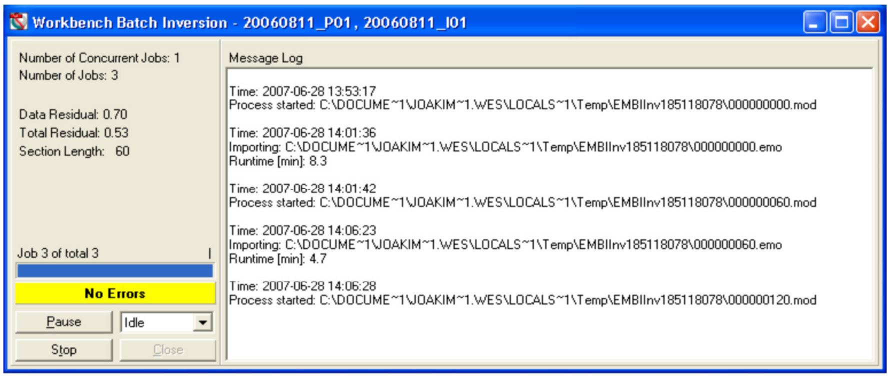



*Figure 35. The EMBI window. In the left side of the screen various information about the inversion process are given*

## 8.2 Evaluation of inversion results

Results can be viewed by selecting **Show Inversion Results**, which is available via the right-click menu on the **Inversion Node**. This opens up the **Model Position Explorer**, which shows a list of the models in chronological order, as seen in Figure 39. Models can be chosen based on their profile number using the drop down.

Selected models are highlighted on the **GIS Map**. The list box layout and functionality can be altered by pressing the **Settings** button, which will be described below.

The menu bar consists of the following buttons in the first row:

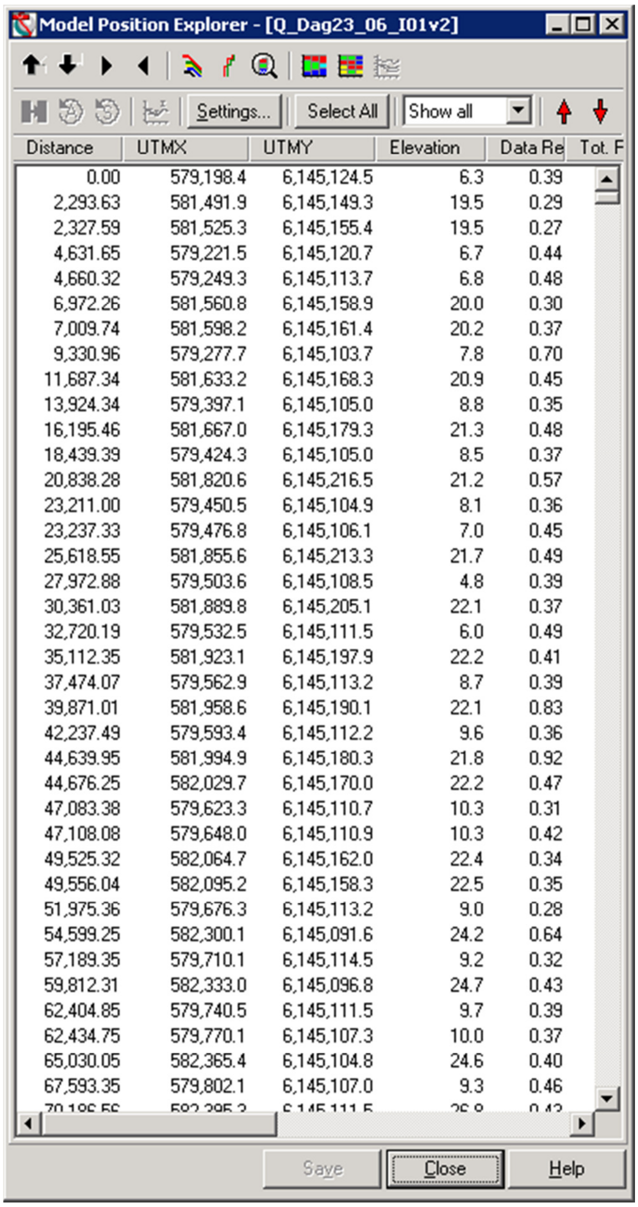



*Figure 36. The Model Position explorer where models can be selected for inspection edited and resubmitted for inversion.*

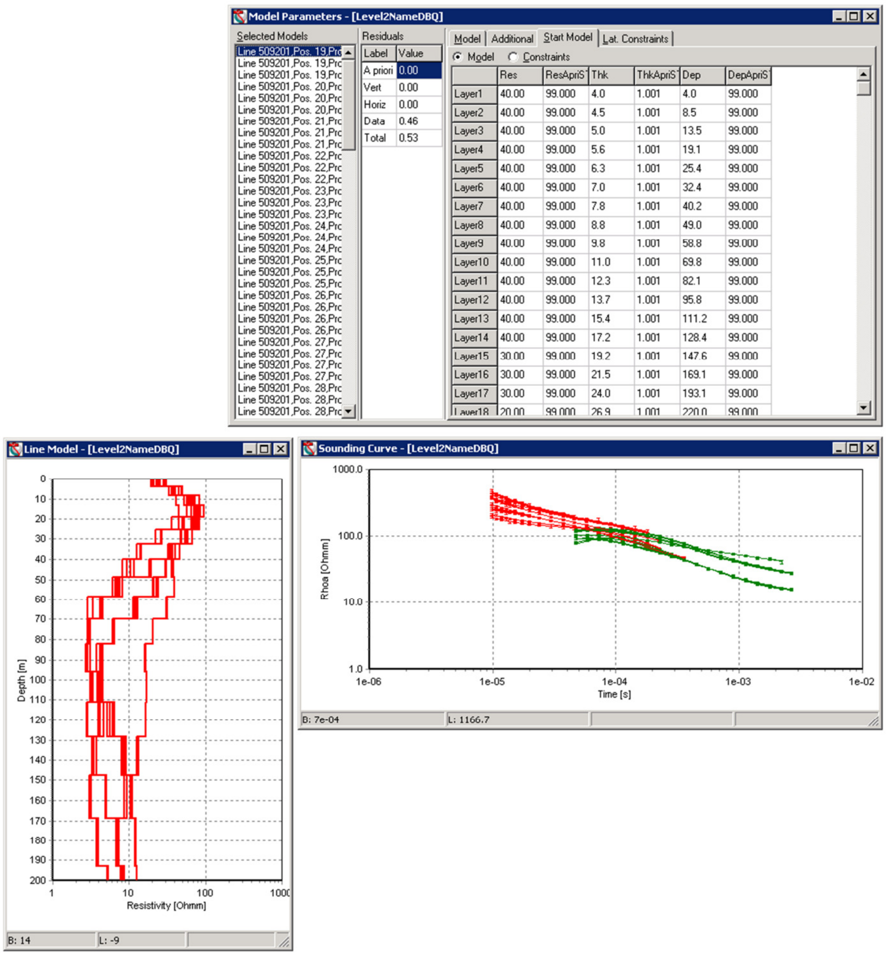



*Figure 37. The views available from the buttons on Model Position Explorer - Sounding Curve, Line Model and Model Parameters*

**Get Previous/Get next**: Moves focus to previous/next models.

**Autoplay/Autoplay backwards**: Automates **Get Previous/Next**.

**Sounding Curve**: Shows data curves of selected soundings with observed data as error-bars and forward data from the inversion as a connected line (Figure 37).

**Line Model**: A line model of the inverted models of the selected soundings (Figure 37).

**View Inversion Results and Start Models**: Holds information about inverted models (including parameter analysis) and starting model (including constraints). Information about input and output altitude and tilt parameters are also found (SkyTEM only). If the starting model has been changed then this will be displayed here (see Figure 37).

**Model Section**: Shows the selected models plotted as bars relative to the profile coordinates or as a filled section.

**Model Analysis Section**: Shows an analysis of the parameters in the selected models. The parameters are shown as colored blocks, with one row per parameter. For a three layer model this is resistivity's 1-3, thicknesses 1-2 and depths 1-2 (the first depth equals the first thickness).

**Data Fit Section**: Shows observed data as error bars with the forward data of the inverted model plotted on top as a connected line.

The **Model Section**, **Model Analysis** section and **Data Fit** forms are shown in Figure 38.

The buttons on the second row are related to the redefinition of models and constraints, resubmission of data for inversion and filtering of unfitted data points. NOTE: Resubmission is not possible with SkyTEM data!

**Create New Starting Model**: Offers the possibility of redefining the starting model of selected models.

**Resubmit All Models in the Explorer for Inversion**: Resubmits all models for inversion.

**Resubmit Selected Models for Inversion**: Resubmits selected models for inversion.

**Filter Unfitted Data**: Offers the opportunity of filtering unfitted data points.

## 8.3 Model Position Explorer Settings

**The Model Position Explorer** Settings form consists of two tab sheets: **Properties** and **Columns.**

In the former different properties concerning the function of the list window can be controlled. It is for example possible to choose GIS Map symbols, the speed of the auto scrolling process, whether all models should be shown or just every other, third, etc. It is also possible to make the GIS map auto focus on selected models if these are close to the edge of or outside the GIS map by ticking on **Auto center map.**

Under **the Columns** tab sheet it is possible to control the layout of the **Model Position Explorer** by specifying which columns should be visible. These vary according to data type but among other include the number of data points, the data - and total residual.

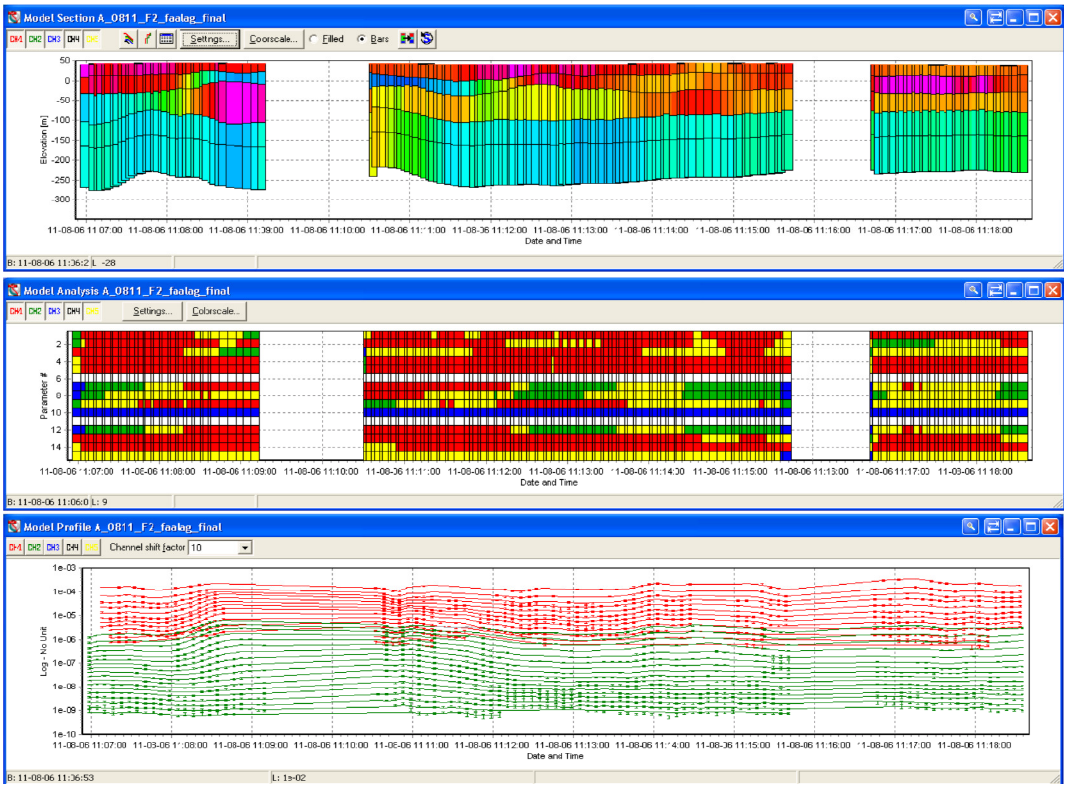



*Figure 38. Model Section (a), Model Analysis Section (b) and Data Fit (c) plots of the same models*

### The Model Section plot

The Model Section plot show the models selected in the **Model Position Explorer** on a depth or elevation section. Models are shown as either model bars or filled sections. Via this plot one or more of these models can be selected and shown on **Model Curve**, **Model Line** or **Model Parameter** plots, just as was the case via the **Model Position Explorer** except that only the models selected on the **Model Section** plot are shown here. Selected models are highlighted on the **GIS Map**.

The **Settings** button opens up a window offering the option to alter things like axis properties, model display and map symbols. It is also possible to shift models along the x-axis making it possible to see otherwise overlapping model bars.

Pressing the **Colorscale** button opens a window showing the current color scale.

Pressing the **Create New Starting Model** button offers the opportunity of redefining the starting model of the models selected on the plot (not the **Model Position Explorer** list box) and pressing the **Resubmit Selected Models for Inversion** submits an inversion job holding only these models. This will be described in greater detail under section 8.4.

## 8.4 Resubmitting inversions

NOTE: Resubmission is not possible with SkyTEM data!

If all or parts of the inversion job needs to be inverted again this can be done using the inversion evaluation system. Typically the user wants to start by trying out the effects of a redefined starting model without having to run the entire inversion job again.

To redefine the starting model of parts of the section and submit only these models for inversion follow these steps:

Select a group of models on the **Model Position Explorer**.

Press **Create New Starting Model**. This brings up the **Create New Starting Model** window.

Enter (altered) layer parameters and/or constraints.

Press **OK** to save the altered model definition for the selected soundings.

Press the **Resubmit Selected Models for Inversion** button.

By following these steps a new inversion is started with only the selected models. The results can be evaluated by pressing **Show Inversion Results** via the right-click menu on the newly created **Inversion Node**. Alternatively the user can select a number of models on the **Model Position Explorer**, plot them on the **Model Section** plot and select a number of these on the plot form. By using the **Create New Starting Model** and **Resubmit Selected Models for Inversion** on the plot form only the models selected on this are resubmitted, not the models selected on the **Model Position Explorer**.

The resubmission of a limited number of models is meant as a way of testing a redefined starting model on parts of a section. After adjusting the starting model where needed the entire inversion job should be resubmitted and the test inversion deleted to avoid duplicate models.

To resubmit the entire inversion job press the **Resubmit All Models in the Explorer for Inversion** button. Alterations to the starting model made prior to this are applied.

The suggested starting model when opening the **Create new Starting Model** form is the output model of the previous inversion. If more than one model is selected one may choose to start the models with individual starting models by ticking on the **Use Inversion Results as Starting Models** box (notice how layer parameters are set to Auto in the **Model** tab sheet). If this is not ticked on the suggested starting model of the selected models is an average of the output models of these. These conditions however only apply to resistivities, thicknesses and depths, not constraints. Constraint factors are set to the tightest constraint for the selected models. This means that:

If the selected models are located across section borders the constraints at these will be redefined.

If one of the models has a priori information/constraints attached to it these will apply for all selected models.

If **Force Continuous** has been used the first model in a section has a priori information attached to it. If this model is selected along with others the a priori will by default apply to all models.

To reset a priori constraints press the **Reset A Priori** button.

Updated starting models are not stated upon reopening the **Create New Starting Model** form (this only states a suggested starting model) but should be viewed using the **View Inversion Results and Start Models** form.

Three typical situations where one may wish to alter the starting model are described below.

## 8.5 Joining layers

When running LCI all models in a section must have the same number of layers. This is however typically not the case from a geological point of view. The solution is to add tight vertical constraints between resistivity's in relevant parts of the LCI section thereby effectively joining layers. To do this the following steps must be taken:

1. Select a number of models where the number of layers should be decreased. This is most easily done using the Model Section plot where results are easily viewable.
2. Evaluate which layers should be joined, i.e. layer 1 and 2, layer 2 and 3,...
3. Press the Create New Starting Model button.
4. Enter a tight constraint (1.001) in the **ResVerSTD** column of the **Constraints** tab sheet. The constraints are given from the top down, i.e. to join layer 2 and 3 the constraint must be entered in the field for layer 2.

Repeat step 1-4 for other models if necessary.

Run the inversion again.

It is not possible to increase the number of layers in a section (i.e. to select 5 layers in an LCI section that was originally run with 4 layers).

### 8.6 Altering horizontal constraints

It may very well be that the constraints need to be changed. They may be too tight, e.g. in a location of rapidly varying geology, or too loose, e.g. does not help to stabilize the inversion. Please follow these steps to do this:

- Select a number of models where constraints should be altered, again preferably using the **Model Section** plot.
- Press the Create New Starting Model button.
- Enter a new constraint in the relevant columns of the **Constraints** tab sheet.
- Repeat step 1-4 for other models if necessary.
- Run the inversion again.

Horizontal constraints are given forward on the section, i.e. if constraints are to be changed between model n and n+1 they should be entered in the starting model of model n.

### 8.7 Adding a priori information

If nearby bore holes, geological knowledge, etc. is to be included in the inversion this can be done by adding a priori information on one or more models. Follow these steps to do this:

- Select a model where constraints should be altered, again preferably using the **Model Section** plot.
- Press the Create New Starting Model button.
- Enter a starting parameter and constraint in the appropriate columns of the **Model** tab sheet, e.g. knowledge of a layer with a resistivity of 10 Ωm in a depth of 40 m may be used by entering 10 in the **Res**, 40 in the **Dep** columns and constraint factors in the **ResApriSTD** and **DepApriSTD** columns. Which layer in the model this should be added to is a matter of evaluating the model result.
- Repeat step 1-4 for other models if necessary.
- Run the inversion again.

# 9. EVALUATION OF INVERSION RESULTS

## 9.1 Model Position Explorer

SCI Inversion results can be viewed by selecting **Show Inversion Result**, available via the right-click menu on the **SCI Inversion Node, which** opens the **Model Position Explorer** in Figure 39.

The inversion results can be inspected line by line, and inversion information for each model is displayed in the list box. Selected models in the list are highlighted on the GIS Map. The list box layout and functionality can be altered by pressing the **Settings** button, which will be described below.

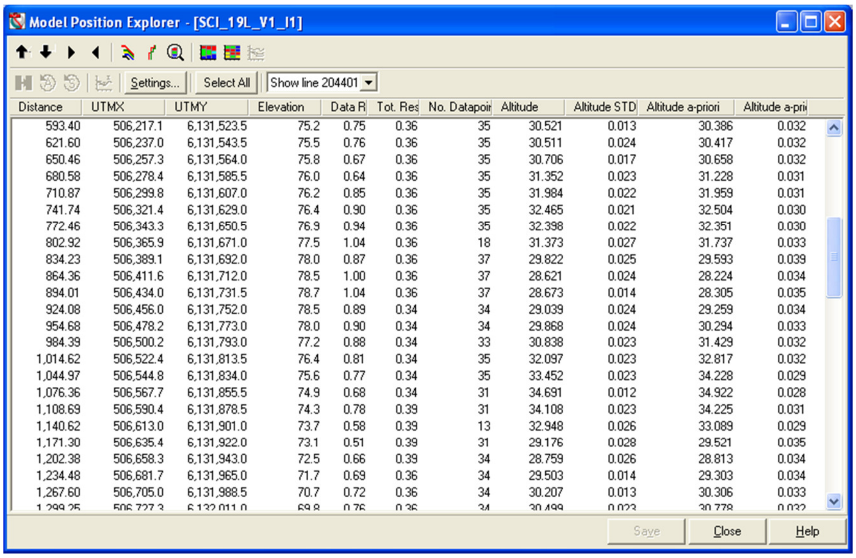


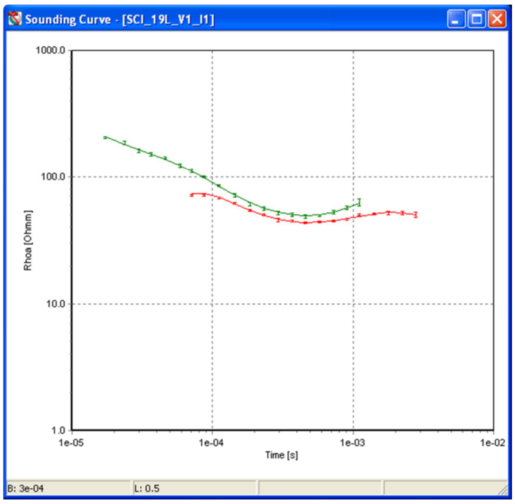

*Figure 39. The Model Position Explorer list box, which can be used to select and evaluate SCI inversion results.*

Typically you will inspect the inversion result using the model section display (see Figure 42) Other key inversion information (from the list box) also can be displayed on the model section. We start with a general description of the **Model Position explorer** (see Figure 41) .

The menu bar consists of the following buttons in the first row:

- **Get Previous/Get next (arrow buttons)**: Move focus to previous/next group of selected models.
- **Autoplay/Autoplay backwards**: Automates **Get Previous/Next**.

- **Sounding Curve**: Shows data curves of selected soundings with observed data with error bars and forward data from inverted model as a connected line (Figure 40, a).
- **Line Model**: A line model of the inverted model results of the selected soundings (Figure 40, b).
- **View Inversion Results and Start Models**: Contains information of inverted models (including parameter analysis) and starting model (including constraints). Information about input/output altitudes and tilt parameters is also available here.
- **Model Section**: Shows the selected models plotted as bars or as a filled section relative to the profile coordinates.
- **Model Analysis Section**: Displays the model parameter analysis of the selected models. The parameters are shown as color blocks, with one row per parameter. For a three-layer model these are: resistivities 1-3, thicknesses 1-2 and depths 1-2 (the first depth equals the first thickness).



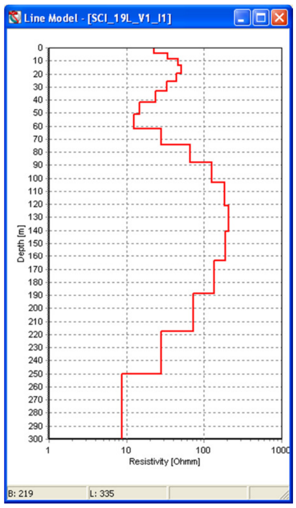



*Figure 40. Model results can be displayed as both sounding curves (a) and line models (b).*

## 9.2 Model position explorer settings

The **Model Position Explorer Settings** form consists of two tab sheets: **Properties** and **Columns** (Figure 41).The properties tab holds different properties concerning the function of the list window E.g. by ticking **Auto center map** it is possible to make the GIS map autofocus on selected models if they are close to the edge of or outside the GIS map.

At the **Columns** tab sheet, it is possible to control the layout of the **Model Position Explorer** by specifying which columns should be visible. They include e.g. number of data points, data- and total residual.

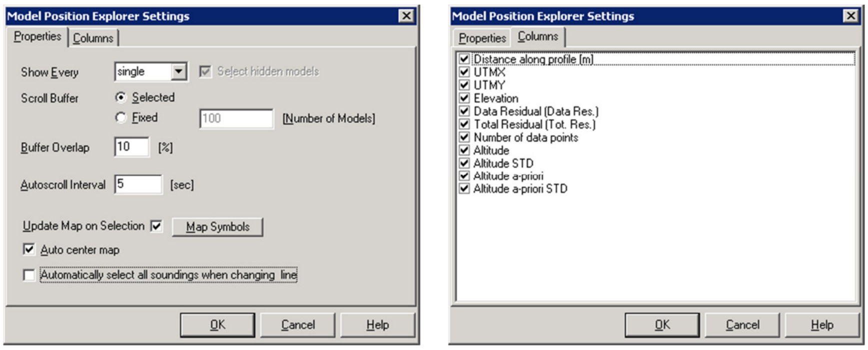



*Figure 41. The Model Position Explorer Settings.*

## 9.3 Model section

Figure 31 shows the **Model Section** form: Figure 42. The selected model in the model position explorer is displayed. Typically, you select one flight line or part of a flight line.

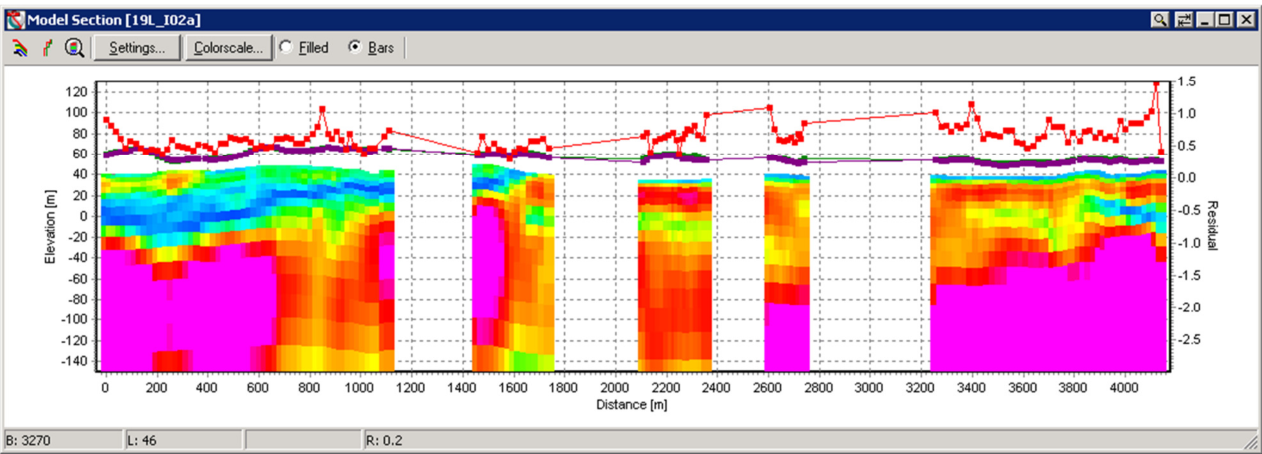



*Figure 42. The Model Section plot can be used to display a selected number of models from an SCI inversion. The red line shows the data fit (residual). Purple and green lines show the measured and inverted altitudes, respectively.*

The **Model Section** plot offers some of the same display possibilities as the **Model Position Explorer** form. If the **Sounding Curve** and **Line Model plot** windows are opened from the **Model section,** only models selected with the mouse pointer on the section are plotted. This allows inspection of line model or sounding curve of only one or a few of the models currently displayed on the section plot.

Model section plot options are found under Settings (Figure 43). Here you can e.g. enable plot of data fit, change the color scale, etc.

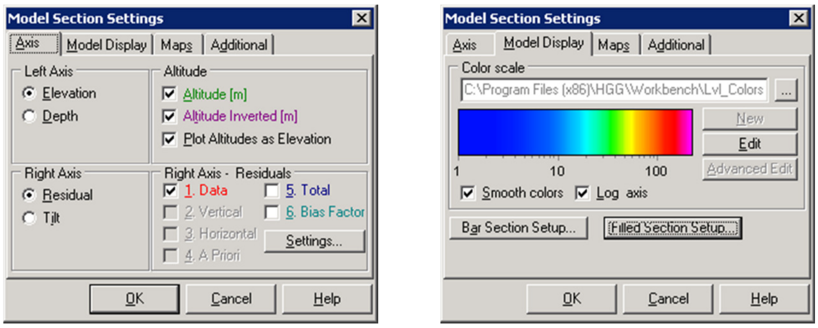



*Figure 43. Model section settings*

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