HydroGeophysics Group

Department of Earth Sciences
University of Aarhus

PROCESSING AND INVERSION OF SKYTEM DATA

V. 1.6

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1 EXERCISE 1: DATA IMPORT

The following exercise demonstrates how to import SkyTEM data to the database in Aarhus Workbench.

Open the Workbench program and load the workspace located in ...\HGG_data\Workspace1.

1.1 IMPORT OF SKYTEM DATA

Importing SkyTEM data to a GERDA database is a three step process: Creating the database in the Workspace Manager, adding a data set to the database and finally importing the data. The two latter is done in the SkyTEM Data Import Window shown in figure 1.1. The window is divided into two sections: Creation of GERDA Dataset and SkyTEM Frame Geometry (geo file) and Raw data, SPS data and Production Mask.

CREATION OF DATABASE

First we must create a database.

1. Right-click on the GERDA node in the Workspace Manager and select New database.
2. Enter a database name.

CREATION OF DATA SETS

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

1. Open the SkyTEM importer via the File/Import. Select Airborne data and Import SkyTEM raw and navigation data. Alternatively select import from the right-click menu on the database.
2. Highlight the Creation of GERDA... radio button in the top of the SkyTEM Data Import window (Figure 1.1).
3. Point to the geometry file. The file is located in ...\HGG_data\Rawdata.
4. Create a data set by highlighting the New dataset button.
5. Press the Settings button to open the SkyTEM Dataset Settings window.

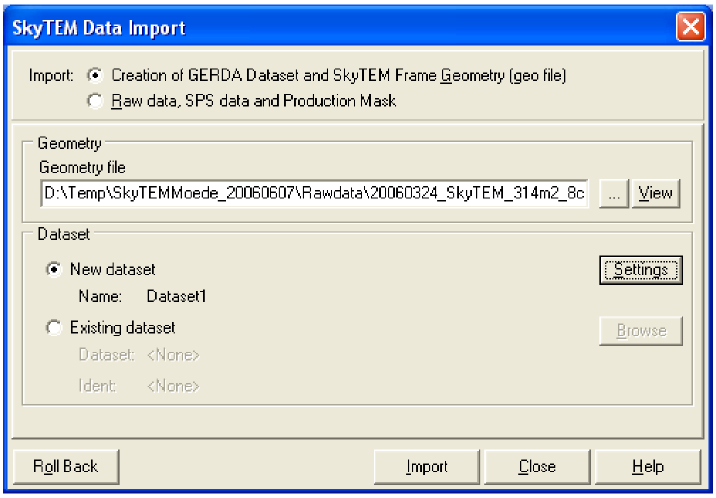

Figure 1.1 The SkyTEM Data Import window, section Creation of GERDA...

Enter a name for the data set and specify the other information needed: coordinate system, datum data etc. In this exercise the coordinate system should be UTM Zone 32 Euref89.

6. Press Import.

A data set with relevant instrument information has now been created. We have also specified to which coordinate system we want all coordinate data transformed to.

Data can also be imported to a previously created data set by highlighting the Existing dataset button.

IMPORTING RAW DATA

Next we must import the raw SkyTEM data:

1. Highlight the Raw data, SPS data... radio button in the top of the SkyTEM Data Import window in figure 1.2.
2. The data set you have just created a is by default selected under Dataset.
3. Make sure the Binary button is selected.
4. Point to the directories holding the skb-files and the SPS-files. The files are located in the folder ...\HGG_data\Raw_data.
5. Select the line file under production: ...\HGG_data\Raw_data\Line_0122.lin
6. Press Import.
7. Select which software channels to data. Select channels 1, 2, and 6, which gives all z-component data and noise data.

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.

HINTS AND TIPS

- Consult the import log from the top menus Map/show log browser to check for error during the import
- Think about your import strategy beforehand: In most cases it is advisable to import all data in one data set and divide them into flights or flight days when you start processing the data.

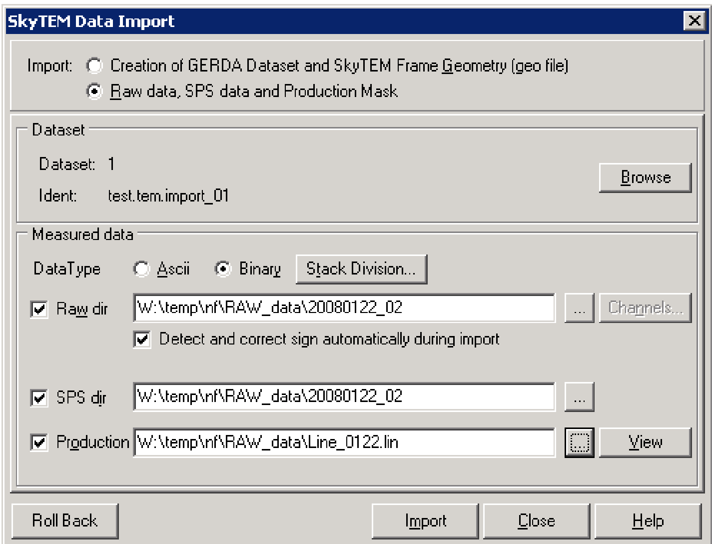

Figure 1.2 The SkyTEM Data Import window, section Raw data, SPS data...

2 EXERCISE 2: SETUP OF PROCESSING, ALTITUDE PROCESSING

This exercise gives an introduction to the processing system. Furthermore the exercise covers the manual corrections of the altitude data.

Automatic processing involves automatic filtering, averaging, etc. of data. We will run an automatic processing of voltage data but will however not go into details with it until exercise 3. The result of the automatic processing is afterwards inspected using the SkyTEM Edit Form, which will be introduced in 2.2.

2.1 INITIALIZING AN AUTOMATIC PROCESSING

Initialize the processing of SkyTEM data by following these steps:

1. Right click on the Map node and select Data processing/New SkyTEM processing. This brings up the Dataset Selector where data belonging to the data sets in the database can be selected.
2. Select which data set to use and enter a name for the processing. This creates a Sky node, which is the link to the data set in the Workspace Manager.
3. Specify which time interval to work on from the New Processing window (figure 2.1). Use the fields From Time and To Time or use the mouse. In this case make a processing of all data from 22/01-2008. It is advisable not to work with more than a couple days production per processing node. The New Processing window is also available from the right-click menu on the Sky node.
4. When the time interval is specified the Processing Management window, seen in figure 2.2 is opened and settings for the automatic processing can be entered. Just use the default settings for now.
5. Tick on all processors including software channels 1, 2 and 6 and press Ok. This creates a Processing node as a subordinate of the SkyTEM Dataset node.
6. The next step is to assign topographical information to the data. Right-click on the Sky node and select Add Topography. Point to the location of the grid file holding the topography data and specify the coordinate system of the topographical data (in this case UTM 32 Euref 89). The grid file is located in ...\HGG_data\GIS.

Topographical information is added to all existing processing nodes and matches UTM coordinates in the grid file with SkyTEM GPS data, i.e. it must be added again if new processings are made or if the GPS processor is run again.

PROCESSING MANAGEMENT

This window is the control center for the automatic processing. The window is divided into five different processors, four concerning the SPS data and one concerning the voltage data (see figure 2.2). When the selected processors are run any previously made automatic or manual processing of these is by default overwritten. It also saves the result of the processing in the database.

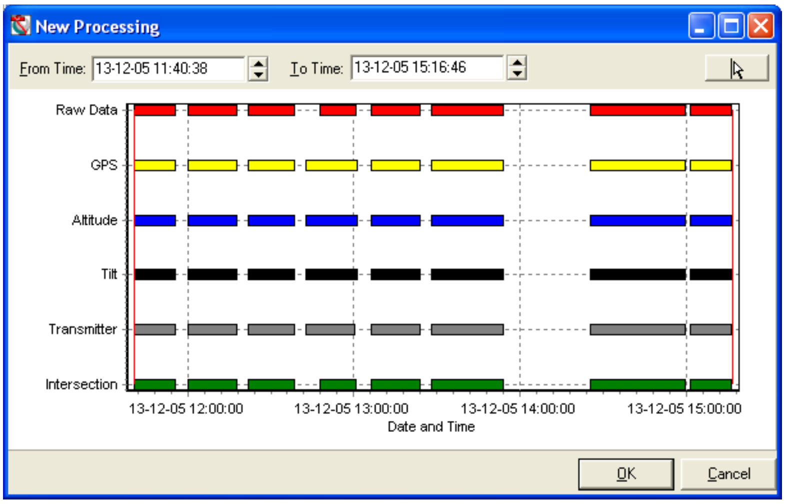

Figure 2.1 The New Processing window where the time interval of the processing can be specified. Colorized bars show the distribution of different data types: Red bar: Voltage data, yellow bar: GPS data, blue bar: Altitude data, black bar: Tilt data, grey bar: Transmitter data and green bar the intersection between these.

2.2 INTRODUCTION TO THE PROCESSING SYSTEM

We will now try experimenting with the processing system to get acquainted with it.

1. Tick on the processing node in the Workspace Manager to see the GPS points on the GIS map.

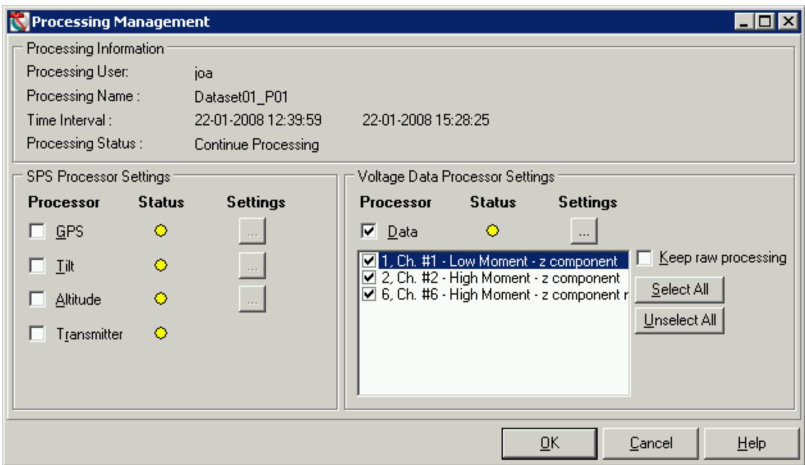

Figure 2.2 The Processing Management window.

2. Right-click on the Processing node and select Plot Data. This opens the Edit Form, figure 2.3.
3. Try plotting different xy series/sub series by ticking on the V boxes.
4. Move the mouse over the plot form and see how the helicopter position is displayed on the GIS map.
5. Press the Buffer button and go to another time interval. Try pressing Ctrl+right/left arrow (or press the arrows on the form) to move the buffer while in the Edit form plot window.
6. Try zooming in on the dot showing the helicopter position on the GIS map and tick the Auto center map found in the top of the form off and on. Move the mouse across the plot form to see the effects.
7. Use the Select SkyTEM tool (Green arrow) which is available via the program bar. Select a GPS point on the GIS map with the tool

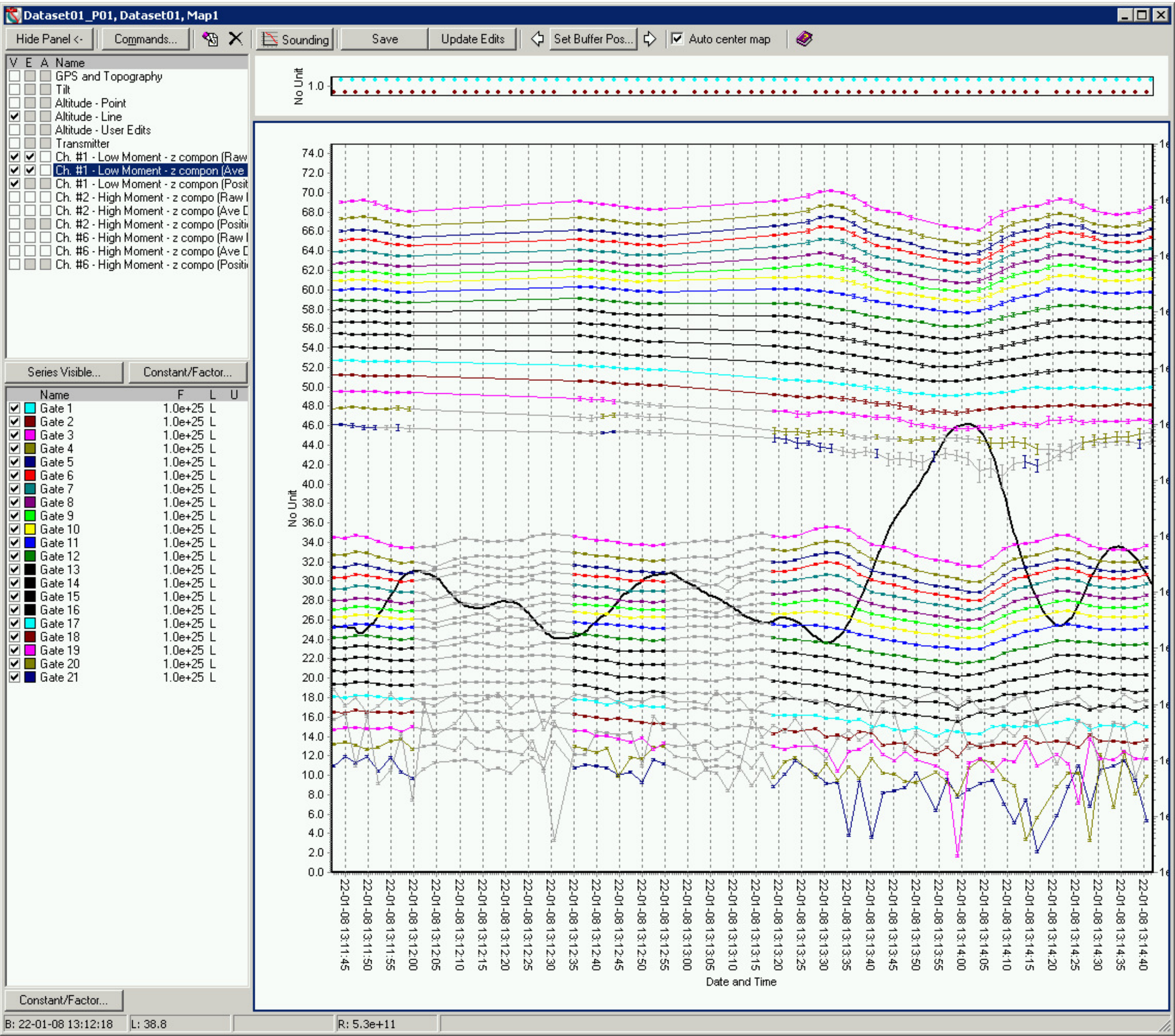

Figure 2.3 The Edit Form. To the right is the collection of XY-series. In this case the plot window shows the altitude (brown line) and as the lower and upper set of colored series raw and averaged voltage data, respectively. Notice the different Y-axes on the left and right side of the plot window, here showing db/dt and altitude values. The plot in the top of the Edit Form shows the position of the raw and averaged soundings.

active and see what happens in the Edit Form.

2.3 THE ALTITUDE DATA PROCESSOR

In this exercise we will experiment with the altitude processor settings.

1. Open the Edit Form by right-clicking on the Processing node and selecting Plot data.
2. Tick on the Altitude - Point collection. Plot the raw data subseries (1 Raw and 2 Raw) and the processed data (Tx Edited) subseries.
3. Find a place with rapidly varying altitude, e.g. set Buffer Start Time to 14:10 and display a 5 minutte interval.
4. Open the Processing Management form again by right-clicking on the processing node and select process data. Try running the processing by decreasing First and Second Filter Lengths to 25. What happens to the processed altitude data?

2.4 ALTITUDE PROCESSING

Altitude processing includes correction of the results of the automatic processing in the form of poly lines drawn by the user. These are found in the Altitude - User Edits series.

The altitude is included as an inversion parameter. Experience shows that even though a wrong altitude is entered in the inversion scheme the output will resemble the true altitude rather well, especially in survey areas where the shallow subsurface is relatively conducting. It is therefore not necessary to make minor corrections.

CORRECTIONS

Lets try making edits to the altitude processing. Follow these steps:

1. Plot the sub series 1 Raw, 2 Raw and Tx Edited under the collection Altitude - Point.
2. Make the Altitude - User Edits series visible.
3. Create a new Altitude - User Edits sub series (use the pencil tool found on the Edit Form).
4. Highlight the newly created sub series that is to hold the edits.
5. Draw a polyline on the plot window in the Edit Form using the Draw Series on Chart tool, (Pencil) which is accessible via the Main program bar. This polyline overrides the original Tx/Rx series in the time interval in question.
6. Apply the changes made to the Rx/Tx series by pressing the Update Edits button of the menu bar. Notice the changes made to the Tx Edited series.
7. Try drawing a dummy series and updating. Notice again the changes to the Tx Edited series.
8. Delete the dummy series by highlighting the appropriate subseries and pressing the Delete Selected Series button in the Edit Form menu bar. In this case the original Tx/Rx series are used again (press Update Edits).
9. Go through more data and repeat step 3-6 where needed.

HINTS AND TIPS

- Try ticking both the Sky node and the corresponding Processing nodes on and use the Zoom to Layer function, which is accessible via the right-click menu on the map window. This can be used to check the success of the GPS data processing by ensuring that no outliers are present.

- Due to the automatic processor hierarchy making an automatic processing of altitude data overwrites any manual processing of the voltage data, while the reverse is not the case. Therefore it is advisable to begin by processing altitude data and concentrate on voltage data afterwards.
- Processor settings can be saved to and loaded from hard disc in the settings windows.
- Manual processing of the voltage data can be kept even though the voltage data processor is rerun subsequently by ticking on Keep raw Processing.
- Useful keyboard shortcuts during processing are shown in table 3.1.

3 EXERCISE 3: 1. STEP VOLTAGE DATA PROCESSING

The following is an exercise in the 1st step voltage data processing. We will however start by experimenting with the automatic processing of voltage data.

No manual corrections can be made to the automatic tilt processing. Keeping an eye on the tilt can however be a good way of explaining oddities in data.

3.1 THE VOLTAGE DATA PROCESSOR

In this exercise we will do experiments with the Cap and Ave filters of the voltage data processor. We will focus on one software channel (High Moment)

1. Open the Edit Form by right-clicking on the Processing node and selecting Plot data.
2. Plot Raw 2, Ave 2 and Positions 2 series (High Moment data).
3. In case the series overlap rearrange them by shift the raw series.
4. Look at the Raw 2 series. Has data been removed by the automatic filters?
5. As the noise level is used in the automatic processing this is important. Look at the Raw 6 series in a db/dt sounding plot and access the signal level at 1 ms.
6. Set all filter values to Default and turn all filters except the Cap Sign and trapezoid filter to Off. Enter the noise level from before and run the processing again. You can now see whether this was the filter that removed data or not.
7. Find a set of settings for the Cap Sign filter which seem to give good results. Remember not to make the filter remove too much data.
8. Go through the rest of the Cap and Ave filters one by one to see the effects.
9. Try saving your processing settings to a file in ...\HGG_data\Processing settings.

Now that we've looked at the Cap and Ave filters it's time to experiment with the Trapezoid filters.

1. Open the Edit Form by right-clicking on the Processing node and selecting Plot data.
2. Plot Raw 2, Ave 2 and Positions 2 series. Show a number of Raw 2 and Ave 2 soundings in sounding Plots. Take a screen dump and paste it in e.g. a Word document also noting approximately which soundings were selected.
3. Open the Processing Management form and open the settings list for the voltage data processor, channel 2.
4. Try decreasing or increasing the Trapez Width 3 for channel 2, run the processing and see what happens to the noise level. Hint: Look at the Raw curves and the corresponding Ave curves of the same sounding curves as before.

3.2 MANUAL VOLTAGE DATA PROCESSING

When the automatic voltage processing has been adequately set up and run it is time to move on to the manual voltage processing.

Generally speaking manual voltage data processing can be divided into two steps. First the removal of coupled data. This is done from raw data as it is vital to remove these before the final data averaging (in the following roughly step 3-4). Second noise processing is carried out (in the following roughly step 7-10). This is done on averaged data as it is important to obtain a better signal to noise ratio before this step.

The removal of coupled data will be done on both data segments simultaneously, while noise processing will be done on one data segment at a time.

1. Plot the Raw 1, Raw 2, Positions 1 and Positions 2 series with the relevant subseries. Make sure the series are Editable (tick on the E box). Also plot the Altitude - Line/Tx Edited series.
2. Shift data series by a factor and adjust the axis if necessary to display the series simultaneously.
3. Make a quick first impression evaluation of data via the profile plot and remove major distortions data before the more time consuming evaluation using sounding curves. Do not worry about details here. Selector tools are available via the program bar or the right-click menu of either the plot windows of the Edit Form or the Sounding Plots.
4. Go through data curves in sounding plots. It may be a good idea to focus on the edges of already spotted coupled locations. As you will probably notice coupling are not always seen in both data segments at the same time.
5. Move on to the next time interval and repeat step 3-4. Repeat until all data in the processing node has been evaluated.
6. This roughly concludes the removal of coupled data even though it is most often the case that further data are removed from the Raw soundings during noise processing. When finished move the buffer to the beginning.

   We will now begin looking at the averaged data to make noise processing (and where needed further adjustments to the raw data).
7. Plot the Raw 1, Average 1 and Positions 1 series (Raw and Average subseries) along with Altitude Line/Tx Edited. Open two Sounding Plots showing dB/dt and Rhoa series for both raw and averaged data. It may also be a good idea to have a Sounding Plot showing raw data open if/when further couplings are found.
8. Go through the soundings by selecting a distinct sounding or a group of soundings at a time via the Positions series or the Sounding List.
9. Remove or add uncertainty to noisy data points of the averaged data series.
10. If necessary remove further coupled data points from the Raw series. Do NOT remove noisy data from Raw data, ONLY remove noisy data from average data. Why? Remember to press the Update Edits button when deleting raw data. Because of the trapezoid shaped filters it is also necessary to evaluate averaged data series (again) from a larger time interval than that from where raw data was removed, e.g. a little backwards in time.
11. Remember to save the processing to GERDA from time to time.

EXTRA EXERCISES

We could also try experimenting with the Trapezoid filters. Try turning Trapez Sync. location of sound off. What happens? Press Help for an explanation.

Try increasing the Trapez Min No. Gates per Sound to 90. What happens?

Sometimes you see the effects of the trapezoid filters very clearly, which will now be shown:

1. Plot data points for Raw 1 and Average 1. Find a place where data has generally not been culled by the automatic filters.
2. Delete the first gate of 3 adjacent Raw 1 soundings.
3. Press Update Edits.
4. What happens to the Average 1 curves at the same time where raw data was deleted? Why?

Galvanic couplings can be hard to recognize but can in general be seen as locations with a relatively high signal level. Look at the data (ch. 2) around 14:18:15. The signal level increases at the same time the altitude increases. Dose this make sense?

HINTS AND TIPS

- Various tools and display properties are available via the right-click menu on plots or series.
- Be careful with using the All property on data series. You may find that you've selected and edited data points that you did not want.
- Data averaging increases the signal to noise ratio, so do not make noise processing of voltage data on raw series.
- Don't show more data than you can handle in the Edit Form, typically 3-5 minutes of voltage data.
- Be conservative when entering noise levels in the automatic processing settings, e.g. if the noise level at 1 ms. is roughly 1e-7 enter 5e-7 or 1e-8 to avoid to much data to be culled.
- Useful keyboard shortcuts during processing are shown in table 3.1.

Shortcut	Function
Ctrl Alt Forward/Back arrow	Moves buffer zone forward/back (main window, Edit Form)
Alt Forward/Back arrow	Moves the x-axis (main window, Edit Form)
Alt a or Alt +	Toggles data points on
Alt q or Alt -	Toggles data points off
Alt # (# denotes keys 1-9)	Adds 5, 10, 15%,... uncertainty to selected data points
Ctrl S	Saves to Gerda
Alt U	Updates the Average series

Table 3.1 Useful processing shortcuts.

4 EXERCISE 4: SCI INVERSION

In this exercise we will run a smooth or multi-layered SCI inversion of the data set we have processed in the previous exercises. LCI is usually done first to make a post processing of the data. Here you will learn how to set a SCI inversion which is generally run after a first post processing on the LCI results. Many of the options and of the menus are identical between SCI and LCI, and are just rearranged in a different order.Later on we will inspect the inversion results.

SMOOTH INVERSION

To set up the inversion job

1. Right-click at the SkyTEM processing node in the Workspace Manager, click New SCI.
2. Check the parameters for the inversion of the flight altitude. Are they pertinent?
3. Click on Channels and Gates..., and check that the channels corresponding to the Z components of the SLM and HM are selected.
4. Click on Next. In the 2nd window choose Data within region click on Select on Map and choose the small isolated set of lines in the North-West part of the survey area, North from Rødding city (maintain the left click and draw a rectangular on the GIS map around the lines).
5. Click on Next. In the 3rd window specify 100 and 75 for Approx. size and Min. size and press Enter on the keyboard so that the sections are evaluated again. You should have 2 sections for this small SCI.
6. In the starting model window, set a smooth inversion with 19 layers with 30 ohmm for all of them (check that the radiobutton Smooth on the right is selected). Check that the first boundary is at 4 m and the last one at 250 m. Note: for changing all resistivities at once you can click on the tab Res.
7. In the tab Constraints set the values of the vertical and lateral constraints for the resistivities to 2 and 1.3 respectively.
8. In the tab Inversion settings, check that the number of parallel processes is maximum 2. Check that the DOI computation is activated.
9. You can have a look at the parameters in Settings under Inversion configuration. In the tab Approximate TEM check that the approximate TEM-response is activated as well as the end with exact iterations. The number of iterations with approximate derivatives only should be equal to 50, and the one with both approximate derivative and approximate forward equal to 0. This will save a lot of computation time with a final result still very accurate.
10. Then click on Finish. After loading the sections a new window, in fact a new program called SCEMBI should start (cf. Figure 4.1).

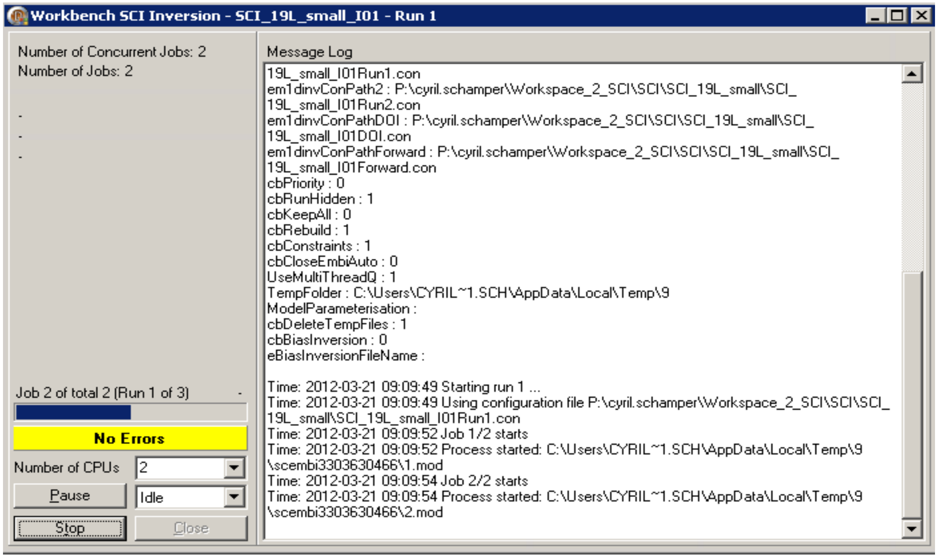

Figure 4.1 The program SCEMBI which controls the SCI inversions.

5 EXERCISE 5: EVALUATION OF INVERSION RESULTS, POST PROCESSING

In this exercise we will evaluate the result from the provisional 1D-LCI inversion and make further processing of the data set.

EVALUATION TOOLS

Select Show Inversion Results, which is available via the right-click menu on the Inversion node. This opens up the Model Position Explorer, holding a list of the models along the flight lines, as seen in Figure 5.1.From here you can inspect the inversion result and make your post processing of the data.

It is recommended to have the columns shown in Figure 5.1 visible. Click Settings/column to set the visible columns on the Model Position Explorer.

The data residual (Data Res. column) indicates if the data fit is acceptable. The input and output altitude columns (Alt, Altl) give you information about the inversion of the altitude - a large mismatch between the input and out altitude indicates problems, either in the processing or the inversion.

The important plot options from the Model position Explorer are (icons at top of the form):

Sounding Curve: Plot-window showing the selected models as model curves.

Line Model: Plot-window showing the selected models as line models.

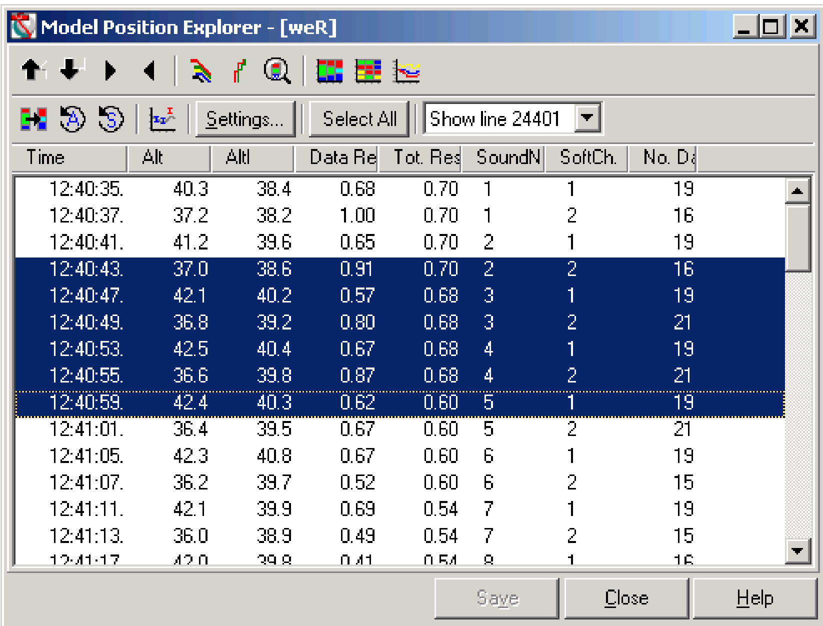

Figure 5.1 The Model Position Explorer.

View Inversion results and start Models: Shows the inversion results and start models. If the starting model has been redefined this will be shown as the start model. Both actual (distance scaled) and normalized constraints are shown.

Model Section: Plot-window showing the selected models as model sections. The altitude and residuals can also be displayed.

Model analysis Section: Shows the parameter analysis of the selected soundings as bars. From top to bottom each bar consists of (n layers in the model) resistivity 1 - n, thickness 1 - n-1 and depth 1 - n-1 separated by blank boxes. Pressing the Colorscale button brings up a colorscale.

Note that selected models are highlighted on the GIS-Map.

5.1 POST PROCESSING

The first step will often be to inspect the inversion result to check the processing. This is why we have run smooth inversions: If a data point is unfitted using a smooth inversion it is a good indication that it should be culled:

1. Open the Model Position Explorer by right-clicking on the inversion node of the provisional inversion and selecting Show Inversion Result.
2. Open a plot showing Sounding curves.
3. Go through a few of the inversion result sounding by sounding and check for poorly fitted data points. Decide whether the data points need to be culled. Note: Culled data become gray.
4. Rather than looking at each individual sounding, use the model section view to plot line by line (or about 100 soundings each time). Chech individual soundings as suggested by unusual high data residuals, large altitude differences or suspicious changes in resistivity layers near data gabs (couplings).
5. Remember to keep an eye on the GIS map while doing this.

The second step is usually to check model positions on the GIS-map (DBQ-check).

1. Open the Edit Form by right-clicking on the Processing node and selecting Plot data.
2. Make a DBQ of the inversion result. Plot both the processing node and the DBQ on the GIS-map. Use the layer control from the GIS-map to ensure that the DBQ is plottet above the processing node while set to not be selectable. What is it that is shown on the GIS-map?
3. Now try using the white arrow from the GIS-map to click on the plotted DBQ. What happened and why?
4. Use the white arrow to recheck the processing along roads and power lines. Upon further inspection one will often find that, if the DBQ shows that data has been removed in most but not all cases, then it should probably have been removed in those last cases as well.

Additional steps include making resistivity maps to look for non geological structures and making thematic maps (VIS) for data and inversion quality control. Both can serve to locate trouble spots that should be reinspected.

1. Right click on an inversion node and select Visualize Data or Inversions.
2. Create VIS themes for overall quality control (default color scales

and settings will be ok in most cases). For this example include number of data points (for all), data residual (for all), total residual, channel number (use the color scale found in

...\HGG_data\segments.lvl with auto scale set to no), altitude inverted, altitude difference, DOI upper/lower.

3. Inspect the overall inversion result for each of these VIS themes. i

5.2 ADDITIONAL INVERSIONS

When the processing has been evaluated and ajusted it is time to set up the next inversion.

SETTING UP A FEW LAYER MODEL

1. Move through the smooth inversion result trying to find out how many layers are needed in the few layer inversion.
2. Try to evaluate the penetration depth. As this may be hard using a smooth model, so consider instead the DOI Upper and DOI lower values found from in the VIS themes.
3. Now that you've got an idea of the basic properties of the inversion setup you're ready to set up a few layer inversion. Right-click at the SkyTEM processing node in the Workspace Manager, click invert data. Select channel 1 and 2 for inversion and select Entire Time Interval. Then select 1D-LCI, Manual from the Inversion type form. Use lateral constraints on resistivities and depth to layer boundaries. Since

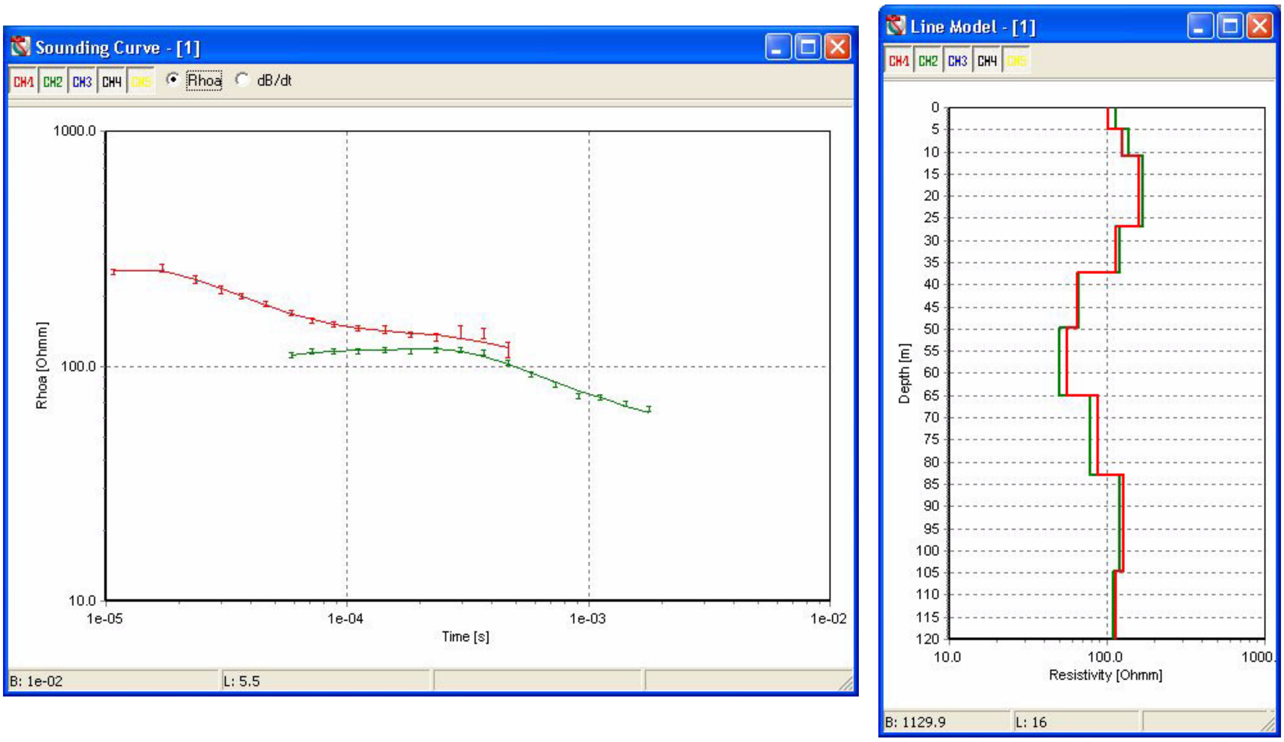

Figure 5.2 Data fit and 1D-model.

the lateral depth constraints are stated relatively you need to tighten up the constraints for deeper layer boundaries.

HINTS AND TIPS

- Place layer boundaries in reasonable depths.
- To stabilize the inversion it may be advisable to set this up with at least one more layer than you expect you need, e.g. if you expect a three layer model use four layers.
- Set the Reference distance to match the actual sounding distance, i.e. 30m.
- If the final result is a LCI it is suggested to setup this LCI with Force continuous models in the manual inversion builder and set the Number of parallel processes to 1 to ensure continuity of the inversion. If on the other hand focus is on speed you could turn Force continuous models off and increase Number of parallel processes.

EXTRA SCI EXERCISE

The final inversion will normally be a SCI. Try going through the wizard setup.

1. Right click on the SKY node and select New SCI. Follow the wizard, but perhaps stop short of actually pressing finish as the creation of the SCI node will take a several minuttes.