

Getting started with SPIA TEM

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1. INTRODUCTION

This document gives a short introduction to the geophysical processing and inversion software SPIA. The software can process and invert Transient ElectroMagnetic data (TEM) measured by the ABEM Walktem, Geonics ProTEM47/57, TEMFAST, HGG WalkTEM and data in USF and AMIRA/ESF format.

The software is developed by The HydroGeophysics Group at The University of Aarhus, Denmark. From October 2015 maintenance and updates for the software are done by Aarhus GeoSoftware. For updates and further information, please visit Aarhus GeoSoftware website www.aarhusgeosoftware.dk.

This guide contains a short overview of the installation and setup of SPIA. The functions of SPIA are explained and a step-by-step example of the complete processing and inversion process is provided, based on a real data example.

This manual refers to SPIA version 3.x.

SPIA has an online wiki page with tutorials and guides. [Click here](#).

1.1 Overview

SPIA is used for processing and inversion of TEM data.

The graphical user interface simplifies the processing and inversion process and has rich possibilities to edit data and models directly in the plots. TEM data can be plotted in different ways, e.g. raw dB/dt, stacked dB/dt and apparent resistivity. Noise and spike filtering are done automatically when opening data in SPIA. The data uncertainty expressed as data standard deviation can be changed for each individual gate, a priori information can be added to the model, and inversion models can be interpreted before making new inversions. The processed data and inversion models are all saved in the same SPIA database and can be imported into Aarhus Workbench for easy visualization of the results.

SPIA can invert for resistivity (normal), but also has the possibility to use a Cole-Cole or Maximum Phase Angle parameter description to model Induced Polarization effects in the TEM data. These inversion modes can be accessed in the advanced inversion tool. References to these inversion methods can be found in chapter 6: References.

The typical workflow for the processing and inversion in SPIA is illustrated in figure 1.1.

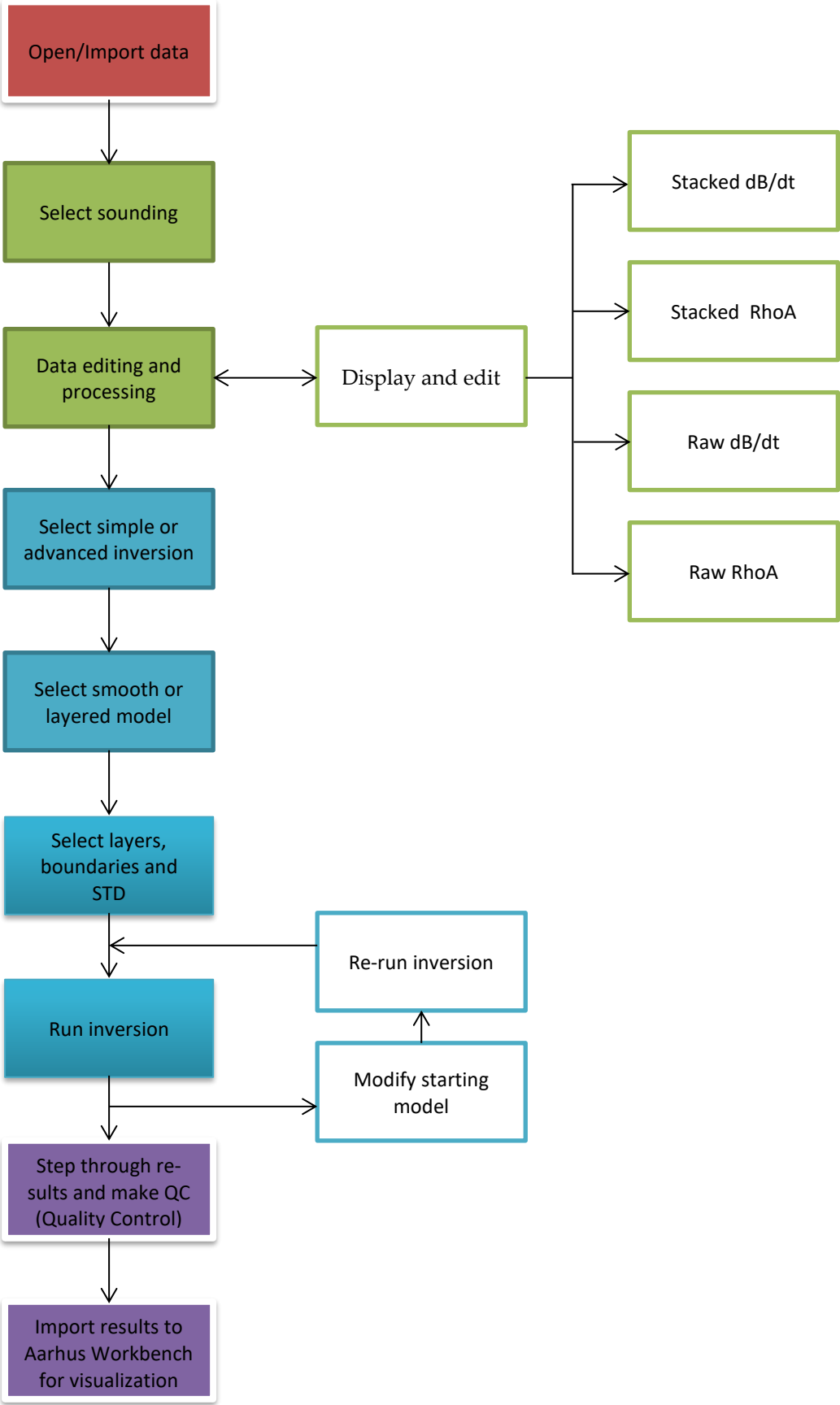


Figure 1.1. Workflow diagram for processing and inversion in SPIA.

2. INSTALLATION AND SETUP

This chapter provides the steps for the installation of SPIA and the demo database.

SPIA is running on **Windows XP, Windows Vista, Windows 7/8 and Windows 10.**

2.1 SPIA

The SPIA software can be downloaded from Aarhus GeoSoftware's website: www.aarhusgeosoftware.dk.

The installation of SPIA is done from a self-extractable exe file. To install, run the executable file and follow the onscreen instructions.

2.2 Demo database

The included demo database is installed with SPIA in:

<SPIA install dir>\DemoWorkspace\

2.3 The license key

Starting the SPIA software the first time after installation, a window will pop up, asking for the license key. This key is obtained from Aarhus GeoSoftware.

3. WORKING WITH SPIA

SPIA has a very easy-to-use and intuitive graphical user interface for processing and inversion of TEM data. The features of the program will be described in the following.

Data and models are stored in a database. The extension of the database file is .gdb. This database is documented on www.gerda.geus.dk and is in Firebird format. Do not make changes to the database unless you are familiar with SQL and relation databases.

3.1 Open data in SPIA

Open data

To create a new project in SPIA, start the SPIA program, press “New Project”, select a folder destination and file name for the project. Then, the import window will open, select importer and follow our import guides:

http://www.ags-cloud.dk/Wiki/S_SPIATEMImportGuides

To open an existing SPIA project, press “Open project” and open the .gdb file containing the TEM data.

3.2 Auto-processing and default options

When the SPIA database is opened, noise- and spike filtering is automatically applied to the data. The settings for the automatically filtering is set in the SPIAConfig.ini file located in the SPIA installation folder. The options in this .ini file are explained in Appendix I. Note: do not make changes to this file unless you are an expert user. Default settings are carefully selected, and it should not be necessary to change them.

3.3 The sounding tree, plot- and information windows

Sounding tree

After opening a SPIA database, SPIA starts up in the Data View tab. To the left, the sounding tree is located (fig 3.1). It contains a sounding node for each location measured with the geophysical system.

By expanding a sounding node, a sub-tree is revealed. Data are grouped into channel nodes, one for each channel measured. Each channel represents one measurement in the sounding with different transmitter moments, low moment or high moment, noise ect. Clicking on any of these nodes, the data points from the selected channel will be plotted. Inversion results will also be listed in the sounding tree within the selected sounding node.

A channel can be drag-dropped into a different station. If channel number does not already exist, the channel is moved. If it exists, the raw data from the two channels is stacked in case the two channels have the same gate times, current, and repetition frequency. Otherwise the channel is assigned a new number and moved.

Several channels can be selected together to compare data curves between channels. Hold Ctrl key when clicking on a channel.

Plot window

When clicking on a channel node in the data tree, the measured data points are plotted in the plot window (fig 3.1). As default, the data points are plotted as a stacked resistivity curve. Formatting of axis, labels and grids can be changed by clicking the left or bottom axis.

Information and model plot window

The window to the right is the information and model plot window (fig 3.1). It shows information on the selected sounding tree or channel node.

For each channel node, the information given is

- Importer
- Importer version
- Repetition frequency
- First gate time
- Last gate time
- Data points in use
- Current
- Stack size
- Front gate time

- Receiver component.
- Rx position. These can be changed if the user wants to correct where the receiver coil is compared to the transmitter coil. This is used if offset receiver is used along with a central loop receiver. The user can then change the position of the offset receiver. The coordinates to specify is the distance from the center of the transmitter frame to the center of the offset receiver frame. The distance can be positive or negative.

For a sounding tree, the following information is available:

- Recording time
- Importer
- First gate time
- Last gate time
- Data points in use
- Move GPS position. If the given GPS location is where the instrument is located, and not the actual center of the receiver coil, this function can move the GPS point to the receiver coil location. Enter the distance and heading to the receiver coil and click the icon. The GPS position will be calculated and updated with the correct position.
- Google maps icon to see the sounding location
- Coordinates in latitude/longitude
- Elevation
- Coordinates in UTM
- EPSG

For an inversion node, the information and model plot window display the starting model and the inversion model results for each parameter, depending in inversion model. This plot is editable when creating a new starting model for inversion. The parameters; resistivity, tau, phi, C and layer thickness can be adjusted selecting the layer interface with the mouse and move it.

For the inversion model, the depth of investigation (DOI) is plotted as a dotted line. A table with the model results and standard deviation (STD) for the inversion parameters, thickness and depth can also be displayed by going to the Model tab and click "Table".

Formatting of axis, labels and grids can be changed by clicking the left or bottom axis.

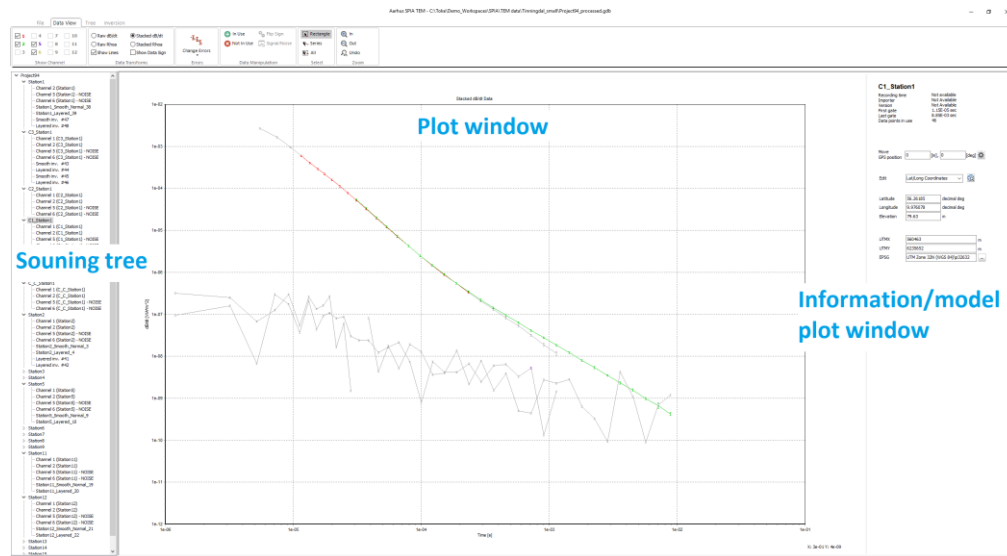


Figure 3.1. The project panel, plot panel and information and inversion result panel in SPIA.

3.4 The File tab

New Project

Create a new project. Saves an empty gdb file and goes to import page for importing data.

Open Project

Opens dialog to browse for a SPIA database.

Open Recent

Shows a list of the ten most recently opened SPIA databases. Click the database name to open one of the databases.

Import

For import, there are 3 options:

Import data from an existing database. The data will be added to a new project in the Sounding tree.

Import data from other data formats (dropdown) to the current project. When selecting a data format, an importer will open that fits the selected data format. Imported data will be

added to the open project in SPIA. See [SPIA wiki main page](#) for import guides.

Import new data from the same database into the existing ABEM WalkTEM gdb.

This function is used if new measurements are added to the same gdb file over time. Then only the new measurements in the gdb file is added to existing gdb where processing and models already exists.

Export

- **Export to column file (xyz)** – exports the selected model(s) with the chosen edition label into .xyz files. Three .xyz files will be created:

The **_inv.xyz** file contains all information of the inversion model, that is the model positioning, layer resistivities (and IP parameters if used), thicknesses and depths.

The **_syn.xyz** file contains the forward model.

The **_dat.xyz** file contains the data used in the inversion.

- **Create Model reports** – exports the selected model(s) with the chosen edition label as a PDF model report, one page for each model.

The exported files are saved in the subfolder \Model_reports in the same folder as the SPIA database.

Show on map

Show the location of the soundings in Open Street Maps. A separate window is opened in your default web browser.

Preferences

Model Plot - choose whether the depth on the model plot should be fixed or automatic based on DOI.

Model Report - choose whether the axes on the data and model plot in

the PDF reports should be fixed or automatic based on DOI and model resistivity.

Also, the logo image can be changed for the model reports.

Rebuild

Rebuild gdb database. This is used if the database contains many soundings and us getting slow after many inversions. Only for advanced users.

Show License

Shows the license under which the program is currently registered. If the license should be moved to a different machine, use the "Unregister this machine" button.

Show Project Log

Showing change done to the data in the project during inversion.

Release history

See the release history for SPIA. Please consult this list to see important updates and new features whenever the program is updated.

Help

Open the main wiki help page for SPIA. It contains data examples, guides etc. Internet connection is needed.

Exit program

Exit SPIA

3.5 Data view tab

Show Channel

In the **Show Channel** window, the different channels can be toggled on or off. When a channel is toggled on, the data from the respective channel can be viewed by selecting the channel in the sounding tree. The channel number is colored corresponding to the color of the data plot.

Data transforms

The raw data transform is normalized with the magnetic moment (M) of the transmitter coil, where $M = \text{Current} * \text{Area} * \text{Number of turns}$.

Raw Rhoa

Plot the data as a raw apparent resistivity curve.

Raw dB/dt

Plot the data as a raw dB/dt curve.

Stacked Rhoa

Plot the data as a stacked apparent resistivity curve data with standard deviation.

Stacked dB/dt

Plot the data as a stacked dB/dt curve with standard deviation.

Show Lines

Determines whether to plot lines between points belonging to the same sweep/channel

Show Data Sign

Gives positive data a blue color and negative data a red color.

Errors

Change Error

Change the error for the selected data points in the plot window. The error can be selected from the dropdown menu.

Keyboard shortcut is *Alt+#*, where # is a number from 1-9. E.g. *Alt+1* adds 5% to the selected data points, *Alt+2* adds 10% etc.

Data manipulation

Disable

Disable the selected data points in the plot window. Keyboard shortcut is *Alt+q*.

Enable

Enable the selected data points in the plot window. Keyboard shortcut is *Alt+a*.

Flip Sign

Available for a selected channel. If data has been imported with the wrong sign, it can be flipped.

Disable Pos

Disable only the positive data points for the selected data.

Disable Neg

Disable only the negative data points for the selected data.

Signal/noise

Change selected channel to a noise or signal channel. Used if a data channel is imported as a noise channel.

Select

Select

Select data points by dragging an area or by clicking a data point in the plot window.

Select all

Drag a square to select entire series within the selection.

Select Series

Select an entire data series by clicking a single point in the series.

Zoom

Zoom in

Zoom into the wanted level by clicking or dragging an area in the plot window.

Zoom out

Zoom out to the wanted level by clicking or dragging an area in the plot window.

Reset zoom

Reset the zoom level to default.

3.6 Tree tab

The **Tree** tab is used to manage the nodes in the **Sounding Tree**. The nodes can be renamed or deleted, and a model report, pictures or csv file can be created. Furthermore, a channel may be drag-dropped into a different station. If channel number does not already exist in the target station, the channel is moved. If it exists, the raw data from the two channels is stacked in case the two channels have the same gate times, current, and repetition frequency. Otherwise the channel is assigned a new number and moved. An undo-button for drag-drop is located in the Tree-tab.

Node Management

Rename

Rename the selected project, sounding tree or channel node.

Delete

Delete the selected sounding tree or channel node. Keyboard shortcut is *Delete*.

Undo Node Dragging

Undo the last drag-drop action. This feature is only enabled until data is altered, i.e. change of STD/In Use flags, or an inversion is started.

Copy Sounding

Copies the selected sounding and creates a new sounding node. The copy function includes already processed data settings.

Export to

Model Report (PDF)

Create a model report in PDF format for the selected inversion model node. The exported pdf model report is saved in the subfolder \Model_reports in the same folder as the SPIA database. The PDF model only shows the results from a resistivity inversion.

Images/csv

Export the selected inversion node's data plot, model plot and model table into PNG and csv files.

3.7 Inversion tab

Standard

In the **Standard Inversion** window, the data can be inverted in auto mode. The processed data is inverted with a smooth model (20 layers) with fixed thicknesses and a layered model (few layers). To run an inversion, a sounding tree needs to be highlighted.

Smoothness

Smoothness refers to the vertical constraints on the resistivities in the starting model. There are three options: low, normal and

high vertical constraints. Setting the constraints to low, normal or high corresponds to factor values of 4, 2 and 1.5 respectively. A factor of e.g. 2 means that the resistivity values between two adjacent layers cannot change more than a factor 2.

Run inversion

Runs the **Standard** inversion. First the depth of investigation is estimated, then a smooth model with 20 layers and the given smoothness and a logarithmic layer distribution down to the depth of investigation is inverted, lastly a layered model based on this smooth inversion result is inverted.

Advanced

In the advanced window, a starting model can be constructed for a smooth, blocky or layered inversion. To edit an advanced inversion, a sounding tree or an inversion model needs to be selected. Press the edit button and a black data curve appears for each channel. This is the forward response based on the starting model. It will update automatically when the starting model is changed. Note: the DOI is not updated when the starting model is changed.

The smooth and blocky models have a large number of layers with fixed thicknesses, whereas the layered model has a few layers with no constraints on thicknesses. Advanced mode also gives the opportunity to customize a model by mouse-dragging the layer segments on the Model chart and by setting the STD values of the layers.

In advanced mode it is possible to choose Cole-Cole or MPA inversion modes besides the normal Resistivity mode. This is if Induced Polarization (IP) effects is affecting the data and want it modeled. The starting model for a Cole-Cole or MPA inversion is crucial and several tries might be needed to get an inversion model that fits the data.

To edit the parameters, standard deviation and layer thickness for a starting model, see **Layer editor** section below.

Edit

To do an advanced inversion, press the edit button when a sounding tree or an inversion model is highlighted to enter advanced mode.

Reset

Reset to the model's initial setup. This function can only be used if the user edits an inversion model and changes the parameters.

Forward Modelling

Enable or disable forward modelling when making a start model.

Load Start Model

It is possible to let SPIA automatically load an external start model from a text file. This is done from the advanced inversion in the Inversion tab. The “Load Start Model” button will ask you to select an external text file. The external starting model will load, and the user can run the inversion.

The format of the text file is:

ModelTypeString=Layered

Layer	Resistivity	ResSTD	Depth	DepSTD
1	100	1.01	10	99
2	50	1.30	110	99
3	60	99	125	99
4	10	2.00		

A file example can be found on the SPIA wiki page. The ModelTypeString can be set to Layered, Smooth or Blocky.

Model Type

Choose model type; Smooth, Layered or Blocky in the dropdown.

Smooth

Use a smooth model for inversion. The smooth model has many layers (9-30 layers) with fixed thicknesses. The layer thicknesses are automatically log scaled after the first and last layer boundary in the starting model.

Layered

Use a layered model for inversion. Layered models have few layers with no constraints on thicknesses.

Blocky

Selecting this option will let the user customize a

blocky model. A blocky inversion will better highlight where the big changes in resistivity are.

Layers

Set the number of layers in the starting model.

Inversion Type

Choose inversion type; Resistivity, Cole-Cole or MPA (Maximum Phase Angle).

Smoothness

Smoothness refers to the vertical constraints on the resistivities in the starting model. There are three options: low, normal and high vertical constraints. Setting the constraints to low, normal or high corresponds to factor values of 4, 2 and 1.5 respectively. A factor of e.g. 2 means that the resistivity values between two adjacent layers cannot change more than a factor 2.

For a layered inversion, there are no vertical constraints for the starting model.

First boundary

Define the depth to the first layer's lower boundary in the starting model.

Last boundary

Define the depth to the last layer's lower boundary in the starting model.

Run inversion

Run the advanced inversion for the selected sounding tree.

Layer editor

In the layer editor window, the starting model can be edited. This can only be used in advanced mode.

Current layer

Select the layer in the starting model to edit.

Resistivity/Tau/C/Phi/Depth

Change the starting parameters for the selected layer. The new parameter setting for the layer will be plotted in the information window.

The user can switch between resistivity/tau/C/Phi and depth by clicking on a layer boundary in the model window.

A priori STD

Change the standard deviation of the parameters for the selected layer in the starting model.

Remove layer

Remove the selected layer in the information window.

Split layer

Split the selected layer in the information window. The selected layer will split into two layers.

Include channels

Select if any channels should be excluded for all soundings when doing inversions. This is used e.g. when two receiver coils are used at the same time and you only invert on the low moment data from one of them along with the high moment from the other.

3.8 Model tab

Depth of investigation (DOI)

Shows the **Depth Of Investigation**. As a means of evaluating inversion results, the **DOI** is calculated. The **DOI** calculation is based on the actual model output from the inversion and includes the full system response. Equally important, the data noise and the number data points are integrated in the calculation. The methodology is based on a recalculated sensitivity (Jacobian) matrix of the final model. The **DOI** is computed using a global and absolute threshold value contrary to defining a relative, say 5%, sensitivity limit.

Layers

The number of layers used in the inversion.

Data residual

Data residual for the inversion model results. A data residual of 1 corresponds to a fit to the data standard deviation for the sounding. So, a residual below 1 means that the model fits the data within the standard deviation.

Label

A label is used to label the inversion model results for later export or display in the Aarhus Workbench.

Each smooth and layered inversion model can be labeled with different labels and the text differs depending on the inversion model. The two label options are either a label describing the kind of model and if a priori information has been used, or a label including the word “final” in front of the previous description.

Only one inversion model result can be labeled “final” for each smooth and layered inversion in a sounding. The model name while be marked with a *. If a model is labeled “final”, any existing model with this label will be relabeled automatically with the other label option.

View

The view window only applies to inversion model results.

Table

Show a table in the information window with the inversion results and STD for the parameters, thickness and depth for each layer in the model. An STD below one means that the model parameter is fitted within the noise. An STD of 0.3 does not mean that the parameter is a better fit compared to an STD of 0.7. Both are fitted within the noise so both are equal likely.

Graph

Show a graph in the information window with the inversion results for the parameters, thickness and depth for each layer in the model.

Model

The model window gives the option to save a model as a new starting model.

Save as start model

Save the current model as a starting model. The model will be loaded when pressing “Edit” in the advanced inversion mode in the Inversion tab.

4. KEYBOARD SHORTCUT LIST

Alt+q

Disable selected data points in the plot window.

Alt+a

Enable selected data points in the plot window.

Alt+#

Change the standard deviation for the selected data points in the plot window.

is a number from 1-9. E.g. *Alt+1* adds 5% to the selected data points, *Alt+2* adds 10% etc.

Delete

Delete the selected tree and node in the sounding tree.

Ctrl+left/right/up/down/enter

Use left/right arrows to toggle between the tabs. Use up/down arrows to select a function within a tab. Use enter to run the function.

Ctrl+h

Open the help file.

Ctrl+o

Open a new project

Ctrl+ right mouse

Select several channels to plot together.

5. DEMO WORKSPACE AND TUTORIAL

Having installed SPIA and the included demo database, the following example can be used to get familiar with SPIA.

The included demo database is installed in:

<SPIA install dir>\DemoWorkspace\

1. Open data

Open SPIA and open the database. It is noticed that there are eight TEM soundings. In this example, only data from Sounding11 will be processed and inverted.

2. Rename

The Sounding11 sounding contains three channels, one for low moment (channel 1), and one for high moment (Channel 2) and one for noise (channel 6). To obtain a better overview, rename channel 1 to “LM” for low moment and channel 2 “HM” for high moment by using the rename function in the tree tab (fig 6.1).

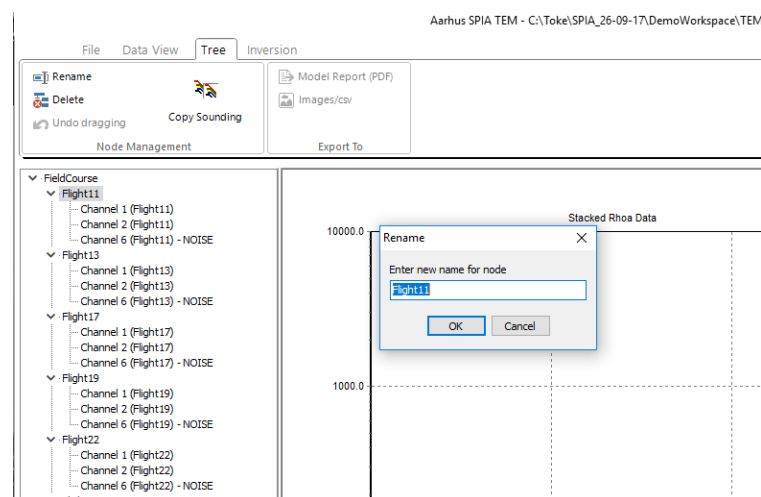


Figure 6.1. Renaming the channels to low moment “LM” and high moment “HM”.

3. Processing

In the data view tab, the data can be plotted in four different ways. All plots are plotted on log-log axis. Each plot supports the possibility of deleting data points, adding additional uncertainty to data points and zooming functions.

Data are trimmed or cut in areas where noise is assumed to have too much influence on the data. This is normally before the data intersects with the noise curves in the raw dB/dt plot. Even though the individual data points are assigned an error bar, it is often necessary to manually add more uncertainty to a data point. When processing, it is important to examine the data in the different plots. As a guide, the following rules apply: **1)** data must be a shift curve without any sudden fluctuations. **2)** The segments must be overlapping between channels.

Looking at the two raw plots, the data points removed by the automatic filtering is grey (disabled). For both LM and HM the automatic processing has kept all the data points for both channels. If any data points need to be enabled (or disabled), it can be done by using the selection tool and the “in use” function (**alt+a**). With the selection tool, a square can be drawn; covering data points and the selected data points can be enabled.

In the two stacked plots, it is noticed that only the first ten data points of HM is enabled by the automatic processing. The HM curve looks smooth with no sudden changes, so the remaining data points needs to be enabled.

The last three data points of the HM have higher standard deviation because they are influenced by noise. We want to raise the uncertainty to 20% for these last data points. Select the last three data points and apply an STD of 20% from the change STD dropdown menu.

The first 12 data points of the HM are not overlapping with the LM. Since we trust the LM more in the early time-gates, these 12 data points can be disabled by using the select tool and the “not in use”-function (**alt+q**). Highlight the HM channel node first, to easier select these data points before disabling them.

The last two data points from LM are not directly overlapping with the data points from the HM. Since they overlap with the HM, these two data points can be disabled without losing information.

The final processed data is seen in fig 6.2.

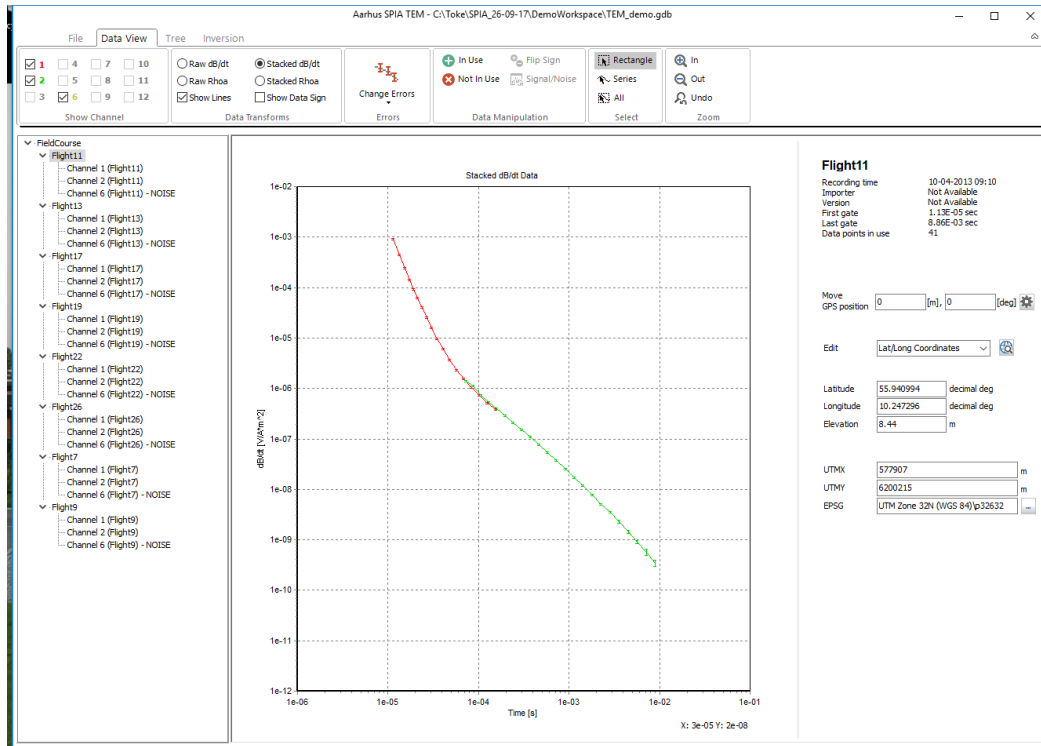


Figure 6.2. Processing result after disabling data and adding uncertainty.

4. Inversion

The data is now ready for inversion. The first thing to do is to make a simple inversion from the inversion tab. Highlight the Sound-ing11 sounding and run a simple inversion with a normal smooth-ness. This gives both a smooth inverted model of 20 layers and a layered inverted model of five layers (fig 6.3). For both inversion models the DOI (Depth Of Investigation) is more or less the same and the residual are low. Looking at the table view for the layered inversion model results, shows that the STD for resistivity, thick-ness and depth are all low and the parameters are well estimated, except for layer 2 due to high resistivity. An STD below one means that the model parameter is fitted within the noise. An STD of 0.3 does not mean that the parameter is a better fit compared to an STD of 0.7. Both are fitted within the noise so both are equal likely.

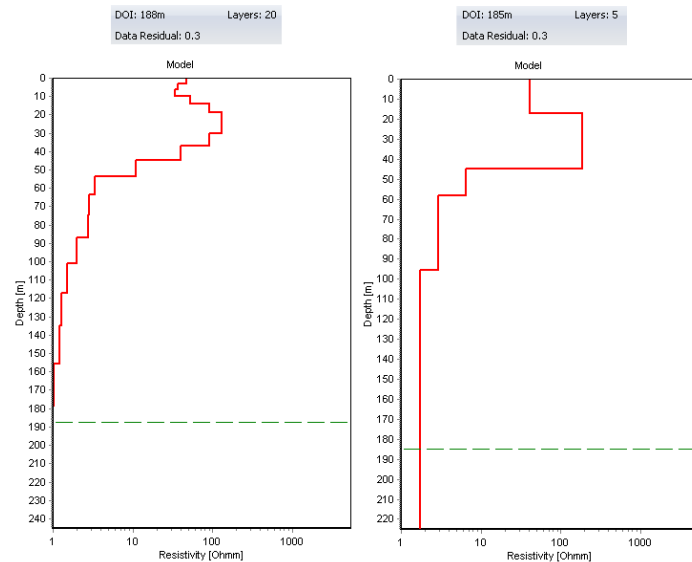


Figure 6.3. Inversion model results for a simple inversion with normal smoothness.

Based on the fundamental minimum length principle, the optimum model is sought as the model which, with a minimum number of layers, gives a satisfying fit of the observed data. So, you must make an evaluation of the physics in the model found.

Does the model contain thin layers at great depth? Or worse: do these layers have a high resistivity? The TEM methods have a poor ability to resolve thin layers at great depth, especially with a high resistivity. These layers should be avoided in the interpretation if no other a priori information exists confirming the existence of these layers.

First after making a thorough geophysical evaluation of your model, you begin to assess the geological validity of the model found. Does the model contain layers with very large resistivity which is geologically highly improbable? The TEM method has a poor resolution when determining the exact resistivity of a layer with high resistivity, and a layer with a resistivity of 1000 Ωm has almost the exact same response as a layer with a resistivity of 100 Ωm . On basis of this knowledge you can add a priori information to a new starting model based on the current model.

5. Advanced inversion

Try making a new advanced inversion. Highlight the Flight11 sounding and press edit. From the earlier inversion model result it is seen that a starting resistivity of 20 Ωm is a better guess than 50 Ωm .

Change this in the layer editor for all layers. Also change the number of layers to 4 with a first boundary of 5 m and a last boundary of 200 m. Run the inversion and compare the inversion model results. It is noticed that the data residual is higher, and the STD in table view are more or less the same.

Other starting models can be tried out, but the best inversion model with the fewest layers is the 5-layer model from the simple inversion. Now this is the model that is decided to be the best to describe the geology in this location and it can be labeled “Final – Layered no prior” in the current model window. This makes it easier to know which model to export later in the file tab.

6. Model report / export of data

Go to File→ export and select models labelled “Final – Layered no prior” and press export to Model Reports. A pdf will be created with all models selected.

Select Export to column file and 3 xyz files will be made for each inversion model:

- .dat file which contains the processed data used in the inversion.
- .inv which contains the inversion model
- .sys which contains the forward response for the inversion model.

It is also possible to export data and model plots into bitmaps and export the table information into a csv file. This is done in the tree tab.

For more training, process and invert the remaining soundings.

6. REFERENCES

SPIA is based on several scientific publications. If you want to read more we refer to the following publications:

Basic principles of TEM

Christiansen, A. V., E. Auken, and K. I. Sørensen, 2006, *The transient electromagnetic method in Groundwater Geophysics. A tool for hydrogeology*: Kirsch, R., Ed., Springer.

Schamper, C., J. B. Pedersen, E. Auken, A. V. Christiansen, B. Vittecoq, J. Deparis, Jaouen T., Lacquement F., P. Nehlig, J. Perrin, and P. A. Reninger, 2013, *Airborne Transient EM Methods and Their Applications for Coastal Groundwater Investigations in Groundwater in the Coastal Zones of Asia-Pacific*: Wetzelhuetter C., Ed., Springer \SCHAMPER2013C.pdf.

TEM IP inversion

Fiandaca, G., E. Auken, A. Gazoty, and A. V. Christiansen, 2012, Time-domain induced polarization: Full-decay forward modeling and 1D laterally constrained inversion of Cole-Cole parameters, *Geophysics*, 77, 3,E213-E225. [pdf](#)

Fiandaca, G., L. M. Madsen, and P. K. Maurya, 2018, Re-parameterizations of the Cole-Cole model for improved spectral inversion of induced polarization data, *Near Surface Geophysics*, 16,385-399. [pdf](#)

Data processing

Auken, E., A. V. Christiansen, J. A. Westergaard, C. Kirkegaard, N. Foged, and A. Viezzoli, 2009, An integrated processing scheme for high-resolution airborne electromagnetic surveys, the SkyTEM system: *Exploration Geophysics*, **40**, 184-192.

Foged, N., E. Auken, A. V. Christiansen, and K. I. Sørensen, 2013, Test site calibration and validation of airborne and ground based TEM systems: *Geophysics*, **78**, E95-E10Inversion

Auken, E., A. V. Christiansen, B. H. Jacobsen, N. Foged, and K. I. Sørensen, 2005, Piecewise 1D Laterally Constrained Inversion of resistivity data: *Geophysical Prospecting*, **53**, 497-506.

Kirkegaard, C. and E. Auken, 2014, A parallel, scalable and memory efficient inversion code for very large scale airborne EM surveys: *Geophysical Prospecting*.

Depth of investigation

Christiansen, A. V. and E. Auken, 2012, A global measure for depth of investigation: Geophysics, 77, WB171-WB177.

APPENDIX I: SPIACONFIG.INI

SPIACONFIG.INI includes settings for SPIA.

```
[AarhusInv]
AarhusInv32=AarhusInv\32bit\AarhusInv32.exe
AarhusInv32_WalkTem=AarhusInv\32bit\AarhusInv32_WalkTem.exe
AarhusInv64=AarhusInv\64bit\AarhusInv64.exe
Inversion=AarhusInv\TEM_inversion.con
DOIInversion=AarhusInv\TEM_Doi_Estimation.con
Inversion_MixedOffset=AarhusInv\TEM_inversion_MixedOffset.con
DOIInversion_MixedOffset=AarhusInv\TEM_Doi_Estimation_MixedOffset.con
Inversion_IP=AarhusInv\TEM_inversion_IP.con

DOI=Lower
LayerThreshold=1.1

SaveAarhusInvOutput=Yes

MinPointsPrChannel=6
IncludeChannels=1,2,3,4,5,6,7,8,9,10,11,12
MaxDistanceBetweenRxCoils4ApproxResponses=1
UseExternalStartModel=0

[DataType]
DataType=

[Processing]

MaxAveSlope=0.6

SkipInitialDatapoints=3

AveSlopeBackStep= 1

NonSpikeFraction=0.1

MinimumdBdt=1E-20
MaxDataSTD=1.3
```

```
Path to 32-bit AarhusINV.exe
Path to 32-bit AarhusINV.exe for WalkTEM
Path to 64-bit AarhusINV.exe
Path to config file for AarhusINV
Path to DOI config file for AarhusINV
Path to config file for offset configuration for AarhusInv
Path to config file for DOI offset configuration for AarhusInv
Path to config file for IP inversion configuration for AarhusInv
```

Upper/Lower - Set which DOI SPIA displays for inverted models.

Constant used to estimate the number of layers used for the layered model from the smooth model in simple inversion mode.

Yes/No - Save output files from AarhusInv. If set to yes, the output files are saved in a subfolder named AarhusInvFiles in the folder location of the .gdb file. Disregard channel with less than the selected number of data points. Disregard channels not listed in the inversion.

Check for when offset config file is used.

Set to **1** to use external start model. Text file must be located with gdb file.

Set to **TEM** if SPIA automatically should start with the TEM module. Set to

DC_schlumberger if SPIA should automatically start with the DC module.

The processing section is settings for the automatic processing the first time a .GDB file is opened in SPIA.

Upper limit for the second derivative of the averaged data point. If a second derivative exceeds this limit, the remaining data points are noise and are set "not in use".

Number of data points which are skipped in the beginning of a measurement before calculating the second derivative.

Number of data points which are set not in use before the iMaxAveSlope limit is met.

The percentage of data points which are set not in use in the top and bottom of the nonspike -filter. Here it is 10% in both ends giving a total of 20 %.

dB/dt values lower than this setting is set to 0.

If the standard deviation of an averaged data point is higher than this setting, the data point is set to not in use.

```
[DataColors]
Channel1=255,0,0
Channel2=0,204,0
Channel3=255,204,0
Channel4=255,0,255
Channel5=0,0,255
Channel6=194,194,71
Channel7=0,255,255
Channel8=163,0,82
Channel9=0,0,0
Channel10=0,0,0
Channel11=0,0,0
Channel12=0,0,0
```

```
[ModelColors]
ModelEdit=0,255,0
ModelEditHighlight=255,0,0
ModelBackground=0,0,255
```

```
[STD]
STD1=Locked/1.001
STD2=0.5 %/1.005
STD3=1 %/1.01
STD4=3 %/1.03
STD5=5 %/1.05
STD6=10 %/1.1
STD7=30 %/1.3
STD8=50 %/1.5
STD9=100 %/2
STD10=Free/99
```

```
[ModelDepthScale]
ModelMaxDepthScaleFactor=1.2
```

```
[MinLayers]
SmoothMode=9
LayeredMode=2
```

RGB values for the 12 data channels.

RGB values for the model plot in the information window.

Values for the Errors dropdown menu.

For calculation of the depth (y-axis) on the model plot. It is calculated as DOI times this factor.

Minimum number of layers allowed for a smooth and layered inversion.

```
[MaxLayers]
SmoothMode=30
LayeredMode=7
```

```
[ModelReport]
Logopath=
ModelResScaleMin=1
ModelResScaleMax=1000
ModelDepthScaleMin=0
ModelDepthScaleMax=300
DataResScaleMin=1
DataResScaleMax=1e03
DataadbdScaleMin=1e-12
DataadbdScaleMax=1e-03
DataTimeScaleMin=1e-06
DataTimeScaleMax=1e-02
AutoScaleModelPlot=No
AutoScaleDataPlot=No
```

```
[Misc]
Contact=Support@ArhusGeoSoftware.dk
maxSoundingsinmem=100
```

Maximum number of layers allowed for a smooth and layered inversion.

Settings for the model report pdf maker. These settings should not be changed.