ABEM GroundTEM i5, i10 & i20
User Guide

ABEM

Our Thanks....

Thank you for choosing Guideline Geo and ABEM! The very core of our philosophy is to provide our users with great products, support, and services. Our team is committed to providing you with the most efficient and easy-to-use solutions with the capability to meet your needs for efficiency and productivity.

Whether this is your first ABEM product, or addition to the ABEM collection, we believe that small investment of your time to familiarize yourself with the product by reading this manual will be rewarded with a significant increase in productivity and satisfaction.

Please let us know about your use and experience of our products as well as the contents and usefulness of this manual. We're excited to be part of your journey!

Guideline Geo AB
www.guidelinegeo.com

WARNING!

THE ABEM GroundTEM DELIVERS HIGH CURRENTS THROUGH THE TRANSMITTER LOOP. CONSIDER ALL CABLES TO CARRY CURRENT, WHETHER CONNECTED DIRECTLY OR INDIRECTLY TO THE GroundTEM.

INSPECT CABLES FOR DAMAGE BEFORE USE. STAY AWAY FROM CABLES WHILE THE SYSTEM IS OPERATING. WEAR ELECTRICALLY INSULATING BOOTS AND GLOVES DURING FIELDWORK.

TO AVOID ACCIDENTS, THE OPERATOR MUST ALWAYS KEEP ALL PARTS OF THE EQUIPMENT INCLUDING INSTRUMENT, LOOPS AND COILS UNDER CLOSE SUPERVISION AND BE AWARE OF UNAUTHORIZED PERSONS AND STRAY ANIMALS APPROACHING WHILE THE SYSTEM IS OPERATING.

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Table of contents

To download the **GroundTEM App** for Android devices from **Google Play**, scan the QR code on the left

Get the **GroundTEM App** (for Android) and other resources from the **Guideline Geo** website, using the QR code to the right

1. Introduction

1.1 What does the user manual contain?

This is a user manual for the GroundTEM i-Series instruments, namely the GroundTEM i5, GroundTEM i10 and GroundTEM i20.

Sections 2 and 4 have a description of the different components of a GroundTEM i-Series system. Field operation of the GroundTEM i5 / i10 / i20 units is described in section 3 (large loops) and 4 (Explorer Coils).

The GroundTEM App is described in section 6 and survey planning and proper instrument handling in section 7.

Appendix 1 includes sections on data processing and visualization of the results in the SPIA/Aarhus Workbench software.

The GroundTEM instrument quick operation guide is shown in Figure 1, further information – such as more extensive quick guides – can be found by scanning the QR code on the inside of the instrument or visiting the downloads section of our website.

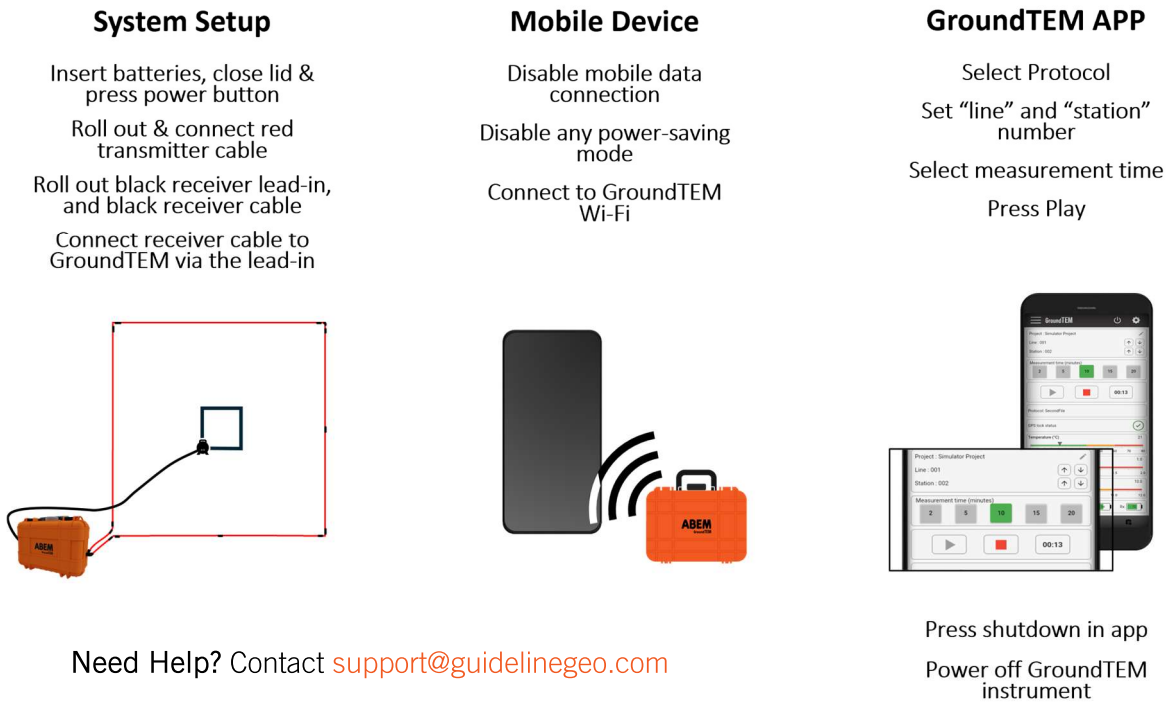

Figure 1. Quick GroundTEM i-Series operation guide.

1.2 The Transient Electromagnetic Method

The measurements are made by transmitting a direct current through the transmitter coil. This results in a static primary magnetic field. The current is shut off abruptly, which induces an electrical field in the surroundings (Figure 2). In the ground, this electrical field will result in an electrical current which again will result in a magnetic field, the secondary field. As time passes, the resistance in the ground will weaken the current (which is converted to heat), and the current density maximum moves downwards and outwards leaving the current density still weaker. In a conductive ground, the current diffuses more slowly down into the ground compared to a resistive ground where the currents will diffuse and decay fast.

The decaying secondary magnetic field is vertical in the middle of the transmitter coil, and an electro motoric power is induced in the receiver coil - a voltage – and this is the signal, which is measured as a function of time in the receiver. Just after the current in the transmitter coil is turned off, the current in the ground will be close to the surface, and the measured signal reflects primarily the conductivity of the top layers. At later times the current will run deeper in the ground, and the measured signal contains information about the conductivity of the lower layers. Measuring the current in the receiving coil will therefore give information about the conductivity as a function of depth – this is often called a sounding.

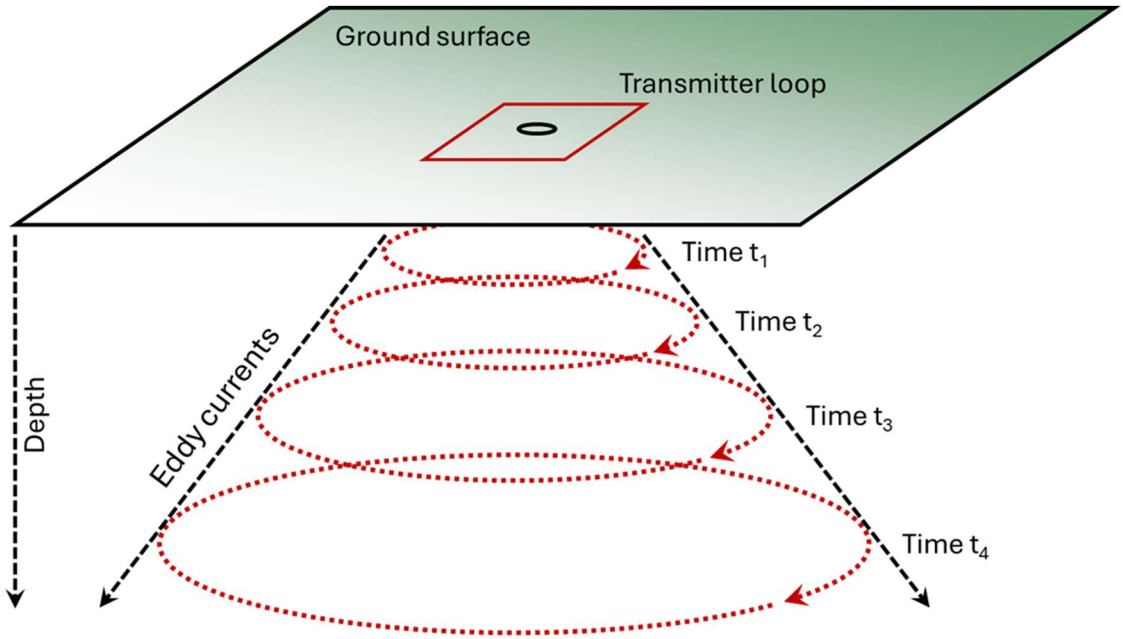

Figure 2.Principal sketch of the TEM method.

2. The GroundTEM i-Series - components

Figure 3 shows the main components of a GroundTEM system.

Figure 3. Main components of the GroundTEM system (apart from the shipping case and two Li-ion batteries).

GroundTEM unit

- Holds both transmitter (Tx) and receiver (Rx) electronics.
- Powered by two batteries (separate battery for Tx and Rx electronics).
- Holds main PC for the real-time signal processing, data storage, etc.

Transmitter coil (Tx loop)

- Size options: 20 x 20 m, 40 x 40 m, 80 x 80 m (split into four 80 m reels)
- Black corner markers on cable to form a square loop (see Figure 6).

Receiver coil (Rx coil)

- Size options: 3 x 3m, 5 x 5m (for use with 80 x 80m Tx loop)
- Yellow corner markers on cable to form a square loop (see Figure 3).

Rx lead-in cable

- Connects Rx coil to GroundTEM unit yellow markers where lead-in crosses Tx loop.

Battery

- Li-ion batteries (two Li-on batteries are needed for i5 / i10, three for the i20).
- Press the stage of charge indicators on the batteries to get to the stage of charge.

Battery charger case

- Battery charging unit for two batteries.

The total system weight for a 40x40 m Tx loop setup including GroundTEM unit is approximately 19.5 kg (excl. battery charging suitcase and shipping case).

3. GroundTEM i-Series - field operation guide

A field crew of two people is recommended to operate the GroundTEM i-Series system efficiently.

The workflow for performing a TEM measurement at one location (a station or a sounding) goes through the following steps:

1. Powering on the GroundTEM unit.
2. Layout of the Tx loop.
3. Layout of Rx coil and Rx lead-in cable.
4. Use the GroundTEM App to collect data.
5. De-mobilize the system.

3.1 Powering on the GroundTEM i-Series unit

To turn on the GroundTEM unit:

- Insert two RRC 2054-2 batteries into the battery slots in the GroundTEM unit (Figure 4).
- Close the case and place it upright (GPS antenna/case handle pointing up).
- Press the power button. The two battery LED indicators should light up (Figure 5).

The third LED light is GPS lock indicator (see Figure 4).

- Blinking if receiving GPS signal.
- Off if not receiving GPS signal.

Note: Powering on and getting GPS lock takes a few minutes, therefore it is recommended to power on the GroundTEM unit before rolling out the cables.

Note: The Tx-battery discharges faster than the Rx-battery. To extend survey time on one set of batteries, the batteries can be swapped when the Tx-battery capacity is down to one bar on the charge indicator.

Figure 4. GroundTEM i-Series unit. Battery cradles and battery LED lights when batteries are inserted.

3.2 Layout of the transmitter coil

Figure 5 show a GroundTEM i-Series layout with a 40x40 m Tx loop and a 3x3 m Rx coil. Different coil sizes follow the same layout plan. The Tx- and Rx-cables have corner markers Figure 6, additionally the Tx-cables have centre markers.

40 × 40 m & 20 × 20 m Tx loop

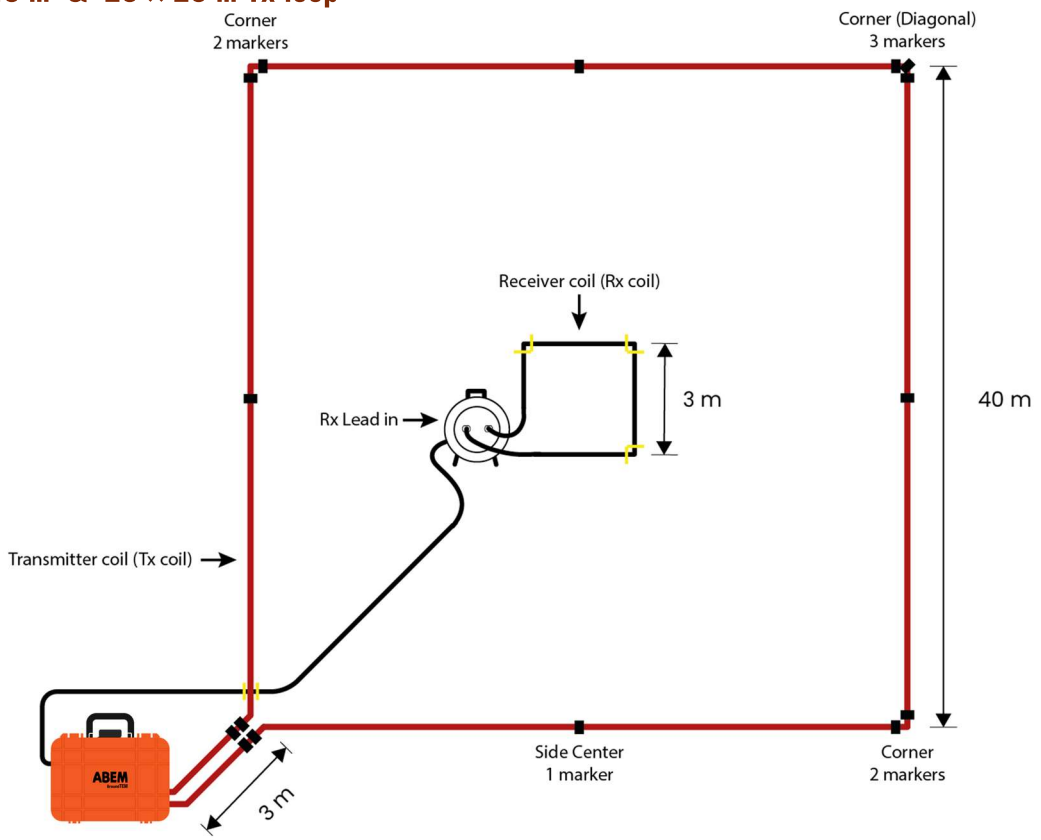

Figure 5. Example GroundTEM i-Series system layout with a 40 x 40 m Tx loop and 3 x 3 m Rx coil. The 20 x 20 m Tx loop only has corner markers.

Figure 6. Tx loop corner marker.

Layout the Tx loop

- Pick a corner position and roll out the first ~3 m of the Tx loop cable to get to the start corner marker (double black marker).
- Walk the cable out in a square, making 90° turns at the corner markers on the Tx-cable.
    - The 40 x 40 m Tx loop has two single cable markers in the 1st 2nd and 4th corner while there are three single markers in the 3rd corner to mark the diagonal. In addition, it has a single centre marker on each side.
    - The 20 x 20 m Tx loop only has corner markers and does not have centre markers on each side.
- If the two sets of markers do not meet up in the corner where the GroundTEM unit is, adjust the Tx loop accordingly. Minor inaccuracies (<1 m off) are acceptable and may be adjusted by a gentle pull of the cable to make the markers meet.
- Move the GroundTEM unit ~3 m outside the Tx loop (see Figure 5) and connect the Tx loop via the banana plugs to the GroundTEM unit (Figure 7). The connection order of the two banana plugs is irrelevant.

Figure 7. GroundTEM banana plugs. Connect Tx loop in any order.

Note:

- The rollout direction (clockwise/anticlockwise) of the Tx/Rx coils is not important.
- If needed, use a stick, plastic or person, to fix the Tx-cable at the corners when rolling out (no metal!). Rocks and stones may damage the cable so avoid that.
- A second person at the corner can also guide the *Roller* to get an accurate 90° angle at the corners.
- A marker of some form (e.g. a stick, ...) at the diagonal corner to the GroundTEM unit will make it easier to position the Rx coil in the centre.
- Tx loop area should match the nominal Tx loop area within a few percentages.

80 × 80 m Tx loop

The 80 x 80 m Tx coil comes on four cable drums. Make sure to identify the two cable drums with the additional 1.5 m Tx-lead-in and use these cables for the 1st and 4th sides of the Tx coil (Figure 8). Follow the coloured connectors in the beginning and at the end of each cable, for easier laying out.

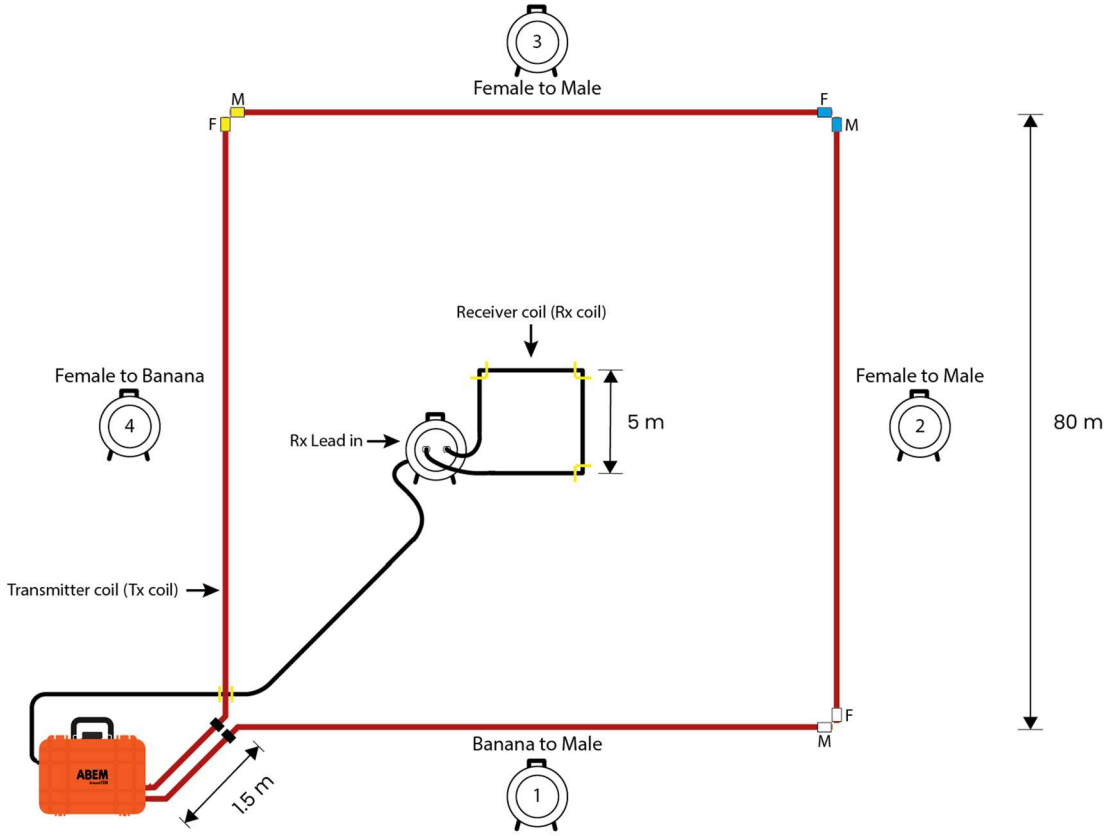

Figure 8 GroundTEM i-Series system layout with an 80 × 80 m Tx loop layout and 5 x 5 m Rx coil.

3.3 Layout receiver coil and lead-in (3 × 3 m & 5 × 5 m)

The Rx lead-in cables are marked with yellow markers to provide the distance from the home Tx loop corner to the first Rx coil corner (see Figure 9). To layout the Rx lead-in and Rx coil:

- At the Tx home corner, pull out the Rx lead-in cable until you reach the first marker (~3 m) and place the marker at the corner.
- Locate the opposite diagonal Tx-corner and walk towards this while rolling out the entire Rx lead-in cable. The end point of the lead-in cable drum marks the first corner of the Rx coil (see Figure 5 and Figure 8).
- Layout the Rx coil in a square as shown in Figure 5 / Figure 8 and connect it to the Rx lead-in cable drum (see Figure 9).
- In the home corner, connect the Rx lead-in cable to the GroundTEM unit. The extra Rx lead-in cable should be placed as in Figure 5 / Figure 8, crossing the Tx-cable perpendicular.

Note:

- Avoid additional cable/lead-in forming a small loop.
- Rx lead-in drum must have the connectors horizontally as shown in Figure 5 / Figure 8.
- Stay away from the Rx coil (stay outside the Tx loop) when recording data.
- Do not place conductive materials (metal) close to the coils, especially the Rx coil.
- An accuracy of the Rx coil centre position within 2 m is acceptable. The Rx coil area should match the nominal area within a few percentages.

Figure 9. Lead-in cable drum (left) with connectors for receiver cable. Yellow marking showing the meeting point between lead-in cable and Tx loop.

3.4 Using the GroundTEM App to collect data

Walk to the corner of the Tx loop where the GroundTEM unit is. For how to operate the GroundTEM App, follow the steps in section 6. Open the app and follow the steps below by selecting:

1. GroundTEM type in settings (i.e. GroundTEM or GroundTEM Explorer Coils).
2. Protocol (i.e. Protocol_TX40x40_RX3x3_20ms_50Hz.sts).
3. Measuring time.

3.5 De-mobilize the system

- Turn-off the GroundTEM from the GroundTEM App and power off the unit with the power button, Figure 4.
- Disconnect cables and put dust caps onto connectors.

To avoid dirt in the plugs, do not drag the plugs over ground when winding up the Rx lead-in and Rx coil cables. The banana plugs on the Tx-cable are simple to clean and can normally be dragged over ground.

4. GroundTEM Explorer Coils – components

Figure 10 shows the main components of the GroundTEM Explorer Coils. These are available in either 3 x 3 m or 1.6 x 1.6 m configurations.

Figure 10. Main components of the GroundTEM system with Explorer Coils, the total system weight for a GroundTEM setup including GroundTEM unit and Explorer Coils is approximately 19.5 kg (excl. battery charging suitcase).

GroundTEM unit

- Holds both transmitter (Tx) and receiver (Rx) electronics.
- Powered by two batteries (separate battery for Tx and Rx electronics).
- Holds main PC for the real-time signal processing, data storage, etc.

Transmitter coil (Tx loop)

- Size options: 3 × 3 m, 1.6 × 1.6 m
- Orange and grey markers indicating the orientation of the coil (see Figure 13).

Receiver coil (Rx coil)

- Size options: 3 × 3 m, 1.6 × 1.6 m
- Orange and grey markers indicating the orientation of the coil (see Figure 13).

Tx & Rx Frames

- 1 cross per frame with red and blue indicators for the coils.
- 1 handle per frame.
- 3 × 3 m Explorer Coils: 4 pairs of white tubes for each frame (16 tubes in total).
- 1.6 × 1.6 m Explorer Coils: 4 white tubes for each frame (8 tubes in total).

Battery

- Li-on batteries (two Li-on batteries are needed).
- Press the stage of charge indicators on the batteries to get to the stage of charge.

Battery charging case

- Battery charging unit for two batteries.

5. GroundTEM Explorer Coils - field operation guide

A field crew of two people is recommended to operate the GroundTEM i-Series with Explorer Coils efficiently.

The workflow for performing a series of GroundTEM Explorer Coil measurements goes through the following steps:

1. Powering on the GroundTEM unit.
2. Assemble the frame and attach the Tx and Receiver coils.
3. Operating the GroundTEM unit from mobile app.
4. Move to next station and repeat.
5. De-mobilizing the system.

The following sub-section provides instructions to perform the different steps.

5.1 Powering on the GroundTEM i-Series unit

To turn on the GroundTEM unit:

- Insert two (i5 & i10) or three (i20) RRC 2054-2 batteries in the battery slots in the GroundTEM unit (see Figure 4).
- Close the case and place it up-right (GPS antenna/case handle pointing up).
- Press the power button. The two battery LED indicators should light up.

The third LED light is GPS lock indicator (see Figure 4).

- Blinking if receiving GPS signal.
- Off if not receiving GPS signal.

Note: Powering on and getting GPS lock takes a few minutes, therefore it is recommended to power on the GroundTEM unit before rolling out the cables.

Note: The Tx-battery discharges faster than the Rx-battery. To extend survey time on one set of batteries, the batteries can be swapped when the Tx-battery capacity is down to one bar on the charge indicator.

5.2 Assembling the GroundTEM Explorer Coils

Follow the 5 steps below to assemble the 3 × 3 m GroundTEM Explorer Coils (Figure 11 - Figure 15); see note at end regarding the 1.6 × 1.6 m variant.

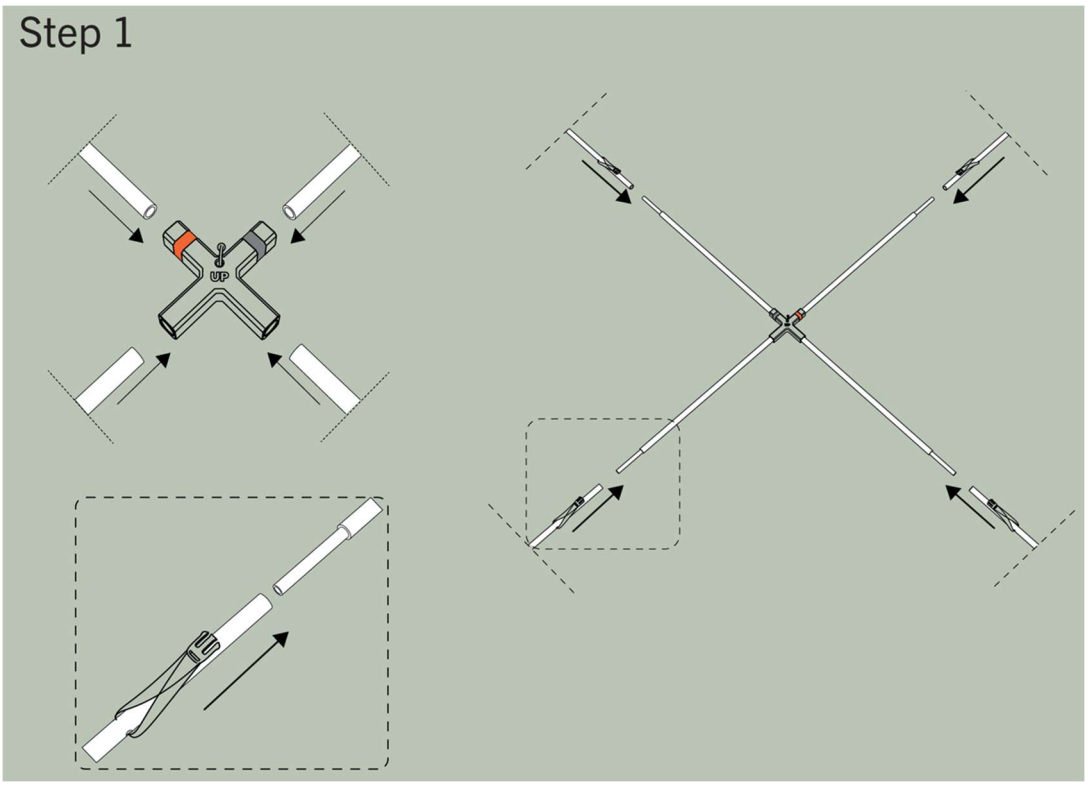

Figure 11. Assembling rods into centre piece.

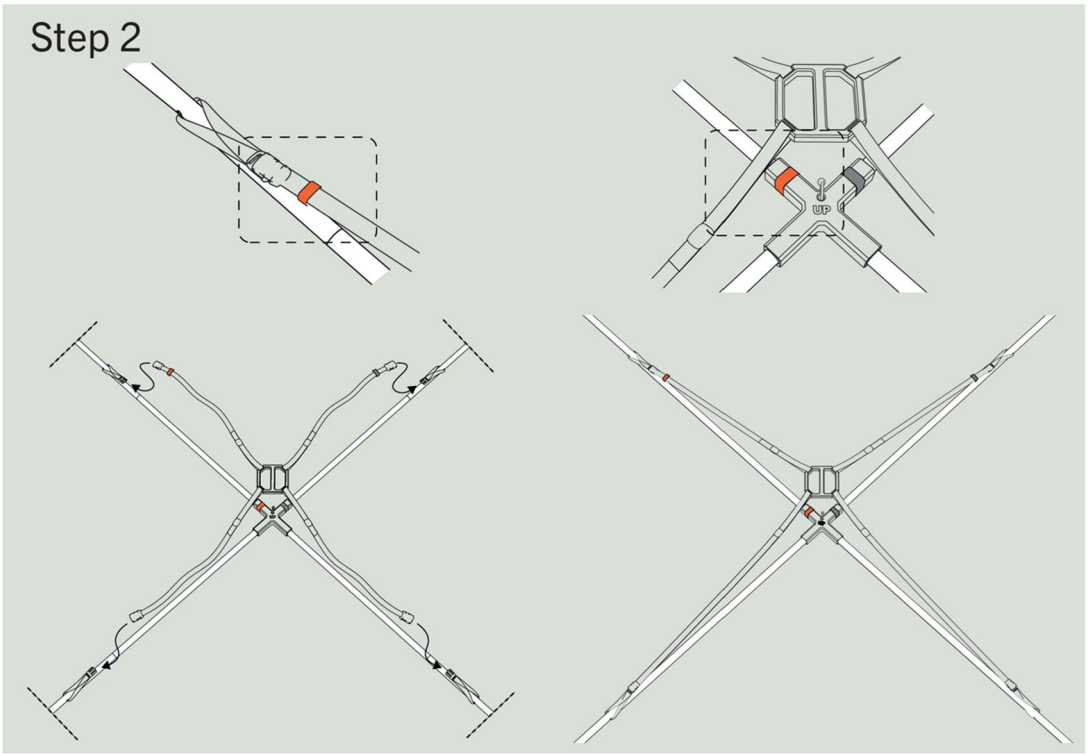

Figure 12. Clipping in the handles.

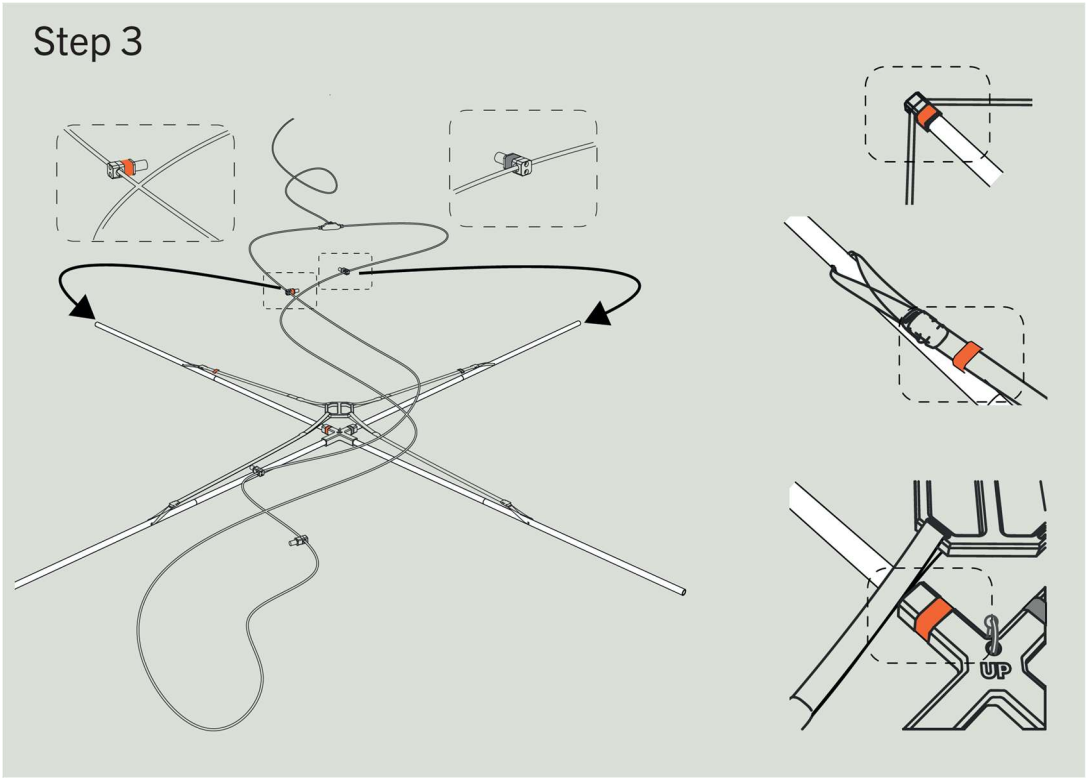

Figure 13. Mounting Rx and Tx coils.

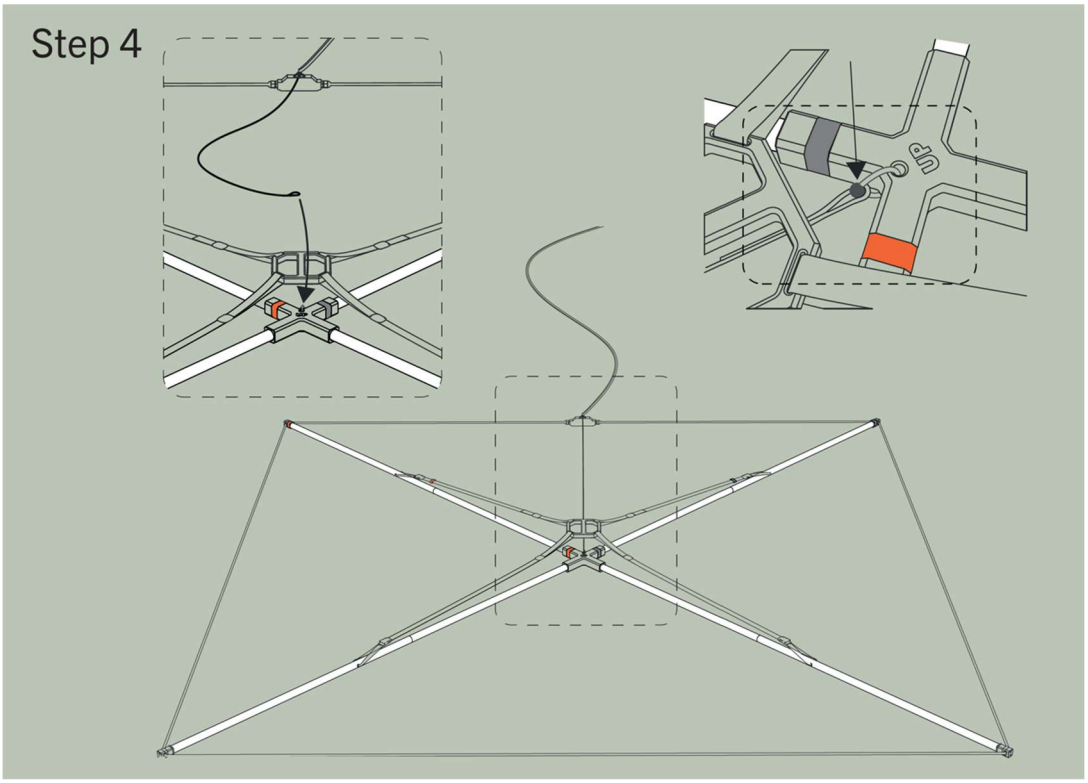

Figure 14. Clipping in strain-relief ropes.

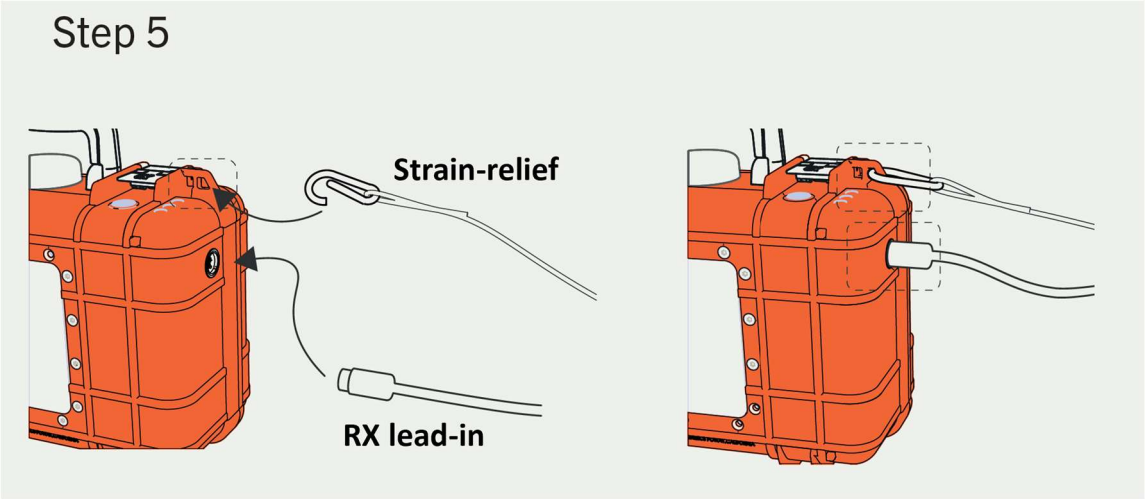

Figure 15. Connecting to GroundTEM instrument.

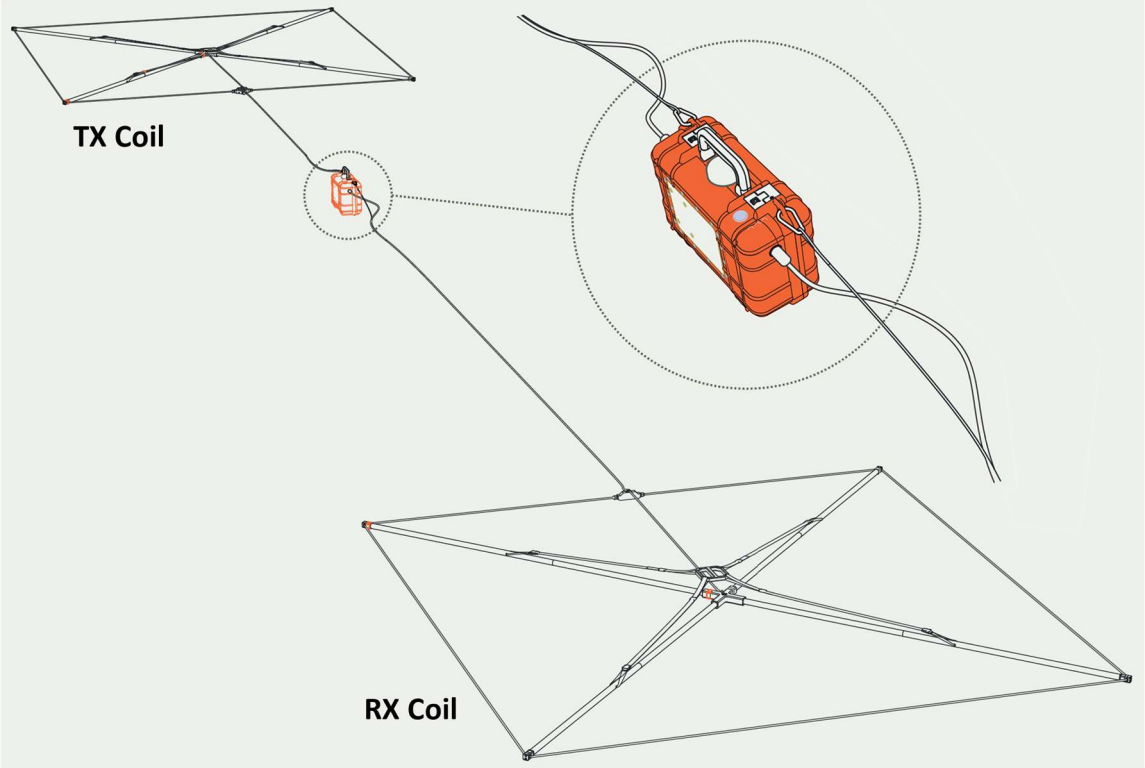

Figure 16. Fully assembled GroundTEM i-Series system with Explorer Coils.

Note: The 1.6 × 1.6 m Explorer Coils only have four poles per coil, i.e. one pole coming from the centre piece out to each of the coil corners. These single poles have the connectors for the handle straps, as shown on the outer poles in the figures above.

5.3 Using the GroundTEM App to collect data

To start the measurement, stand behind the transmitter coil (Tx coil). For how to operate the GroundTEM App, follow steps in section 6. Open the app and follow the steps below by selecting:

1. GroundTEM type in settings (select GroundTEM Explorer Coils)
2. Protocol (e.g. Protocol_TX3x3_RX3x3_4600us_50Hz.sts)
3. Measuring time (e.g. 1 or 2 minutes)

Note: When using GroundTEM Explorer Coils, the automatic signal polarity sensing is disabled. This means that it is possible to collect negative data if the coils are incorrectly assembled or the "banana" connectors are reversed on the Tx connection. Run a short measurement, look at the data plot and ensure that the decay curves are red. If the curves are blue, stop the measurement and swap the Tx banana connectors on the side of the box.

Note: When GroundTEM Explorer Coils mode has been set in the app, there is no notification for turning off the system after completing a sounding.

5.4 Next station

Pick up the Explorer Coils and GroundTEM unit and move to the next station. Place Explorer Coils down and move out of the loops before measuring.

5.5 De-mobilize the system

- Turn-off GroundTEM from the GroundTEM App and power off the unit with the power button on the GroundTEM.
- Disassemble Explorer Coils and put the dust caps on the connectors.

6. GroundTEM App

Installing the GroundTEM App

The GroundTEM system is controlled by the GroundTEM App (see Figure 17), which is available for Android and can be installed from Google Play (search for *GroundTEM* or follow the link from our webpages – both can be linked to via the QR codes beneath the

Table of contents).

Figure 17. GroundTEM App icon.

Connecting to the GroundTEM unit

- Make sure the GroundTEM unit is turned on. It needs to run for a few minutes to set up the GroundTEM Wi-Fi.
- From the mobile device, connect to the GroundTEM Wi-Fi network.
  Wi-Fi name: GroundTEM#### (ID of the GroundTEM instrument).
  Password: GroundTEM (Case sensitive)
- Turn off the mobile data network to prevent the device automatic switching to this connection and thereby turning off the Wi-Fi connection to the GroundTEM unit.
- Open the GroundTEM App, which should display the controller interface as shown in Figure 18, if properly connected.

GroundTEM App - Introduction

Figure 18 explains the interface of the GroundTEM App.

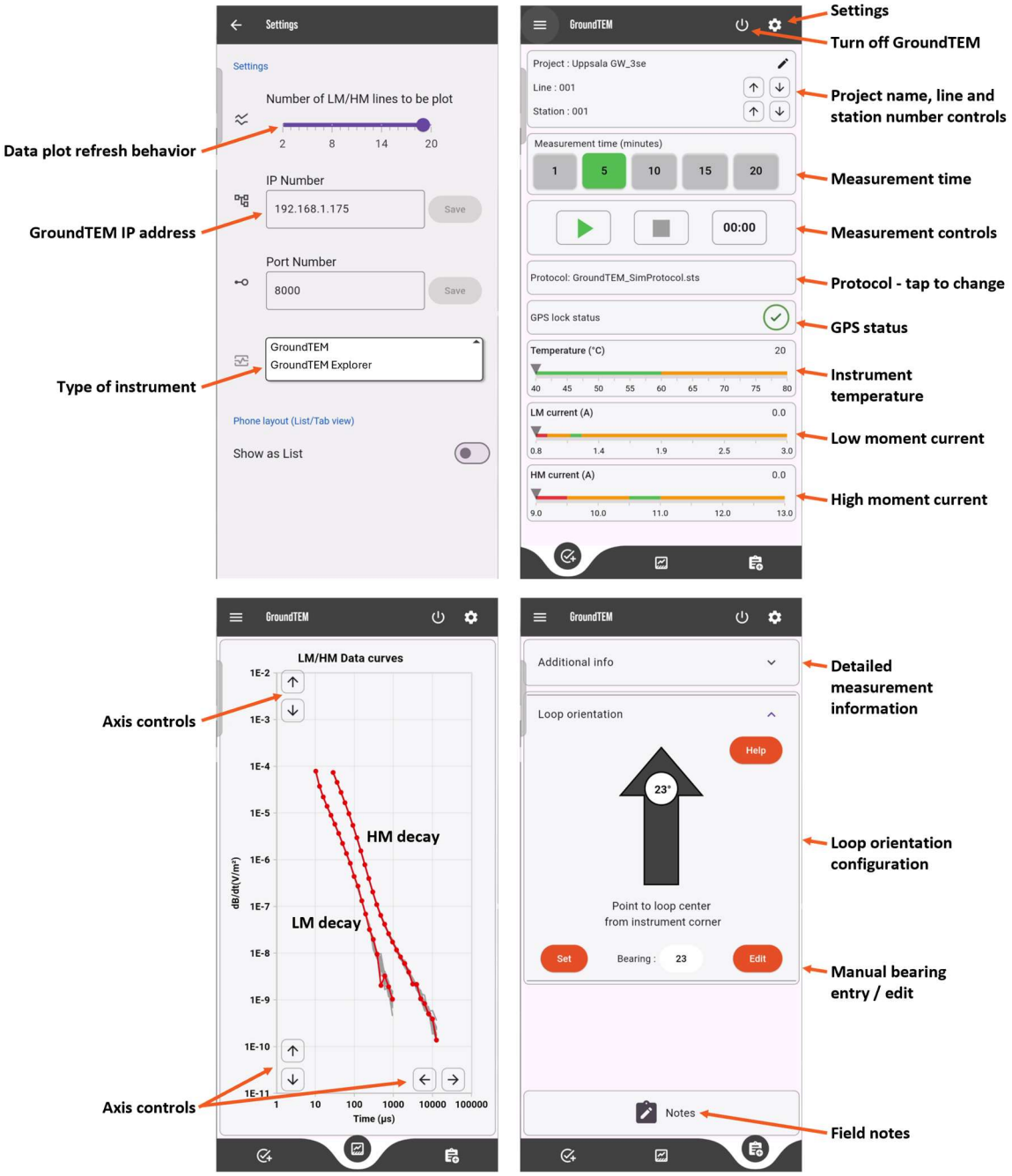

Figure 18. GroundTEM App environment. Version 1.1.0.

Protocols

The protocol file defines the measurement sequence of the GroundTEM unit and contains key information for accurately modelling the data (layout geometry, transmitter waveform, etc.). It is essential that the correct protocol for a given setup is selected. The protocol files are named as the example in Figure 19. The Tx- and Rx coil size need to match the layout, and the powerline frequency (50 or 60 Hz) need to match the powerline frequency of the country. It is only possible to select from pre-prepared protocols.

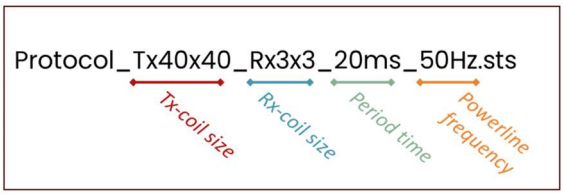

Figure 19. Protocol naming.

Performing a measurement

- Check/set *Project* name, *Line* number and *Station*. The *Station* number will automatically increase by one when ending a measurement (ready for next measurement).
- Set the measurement time.
- Check/load *Protocol,* see Figure 18. The previous used protocol is automatically loaded.
- Press *Play* button to start the measurement.
- The measurement will end when the *timer* reaches the selected *measurement time* or if the stop button is pressed. The stop button can be pressed at any time.
- The GroundTEM unit records the GPS position where the unit is placed. To correct the GPS-position to the centre of the Rx coil, the bearing (geographical direction) from the GroundTEM unit to the Rx coil centre is needed. When stopping a measurement, you will be prompted to set a bearing using the built-in compass of the mobile device. You can also set the bearing during a measurement from the *Additional* tab/*Loop Orientation* (see Figure 18).
- When measurement is done, use the Turn-off button in the GroundTEM App to turn-off the GroundTEM PC, before powering off the GroundTEM unit.

Note: If the connection between the GroundTEM unit and mobile device is broken, the measurement will continue until the set *measurement time* is reached. Re-connection to the GroundTEM is possible.

Note: Several mobile devices can be connected to the GroundTEM unit at the same time and monitor the data recording, but only the device that started the measurement can stop the measurement.

Monitoring a measurement in real time

The GroundTEM alternates between sequences of low moment (LM) and high moment (HM) transmitter pulses. During a measurement you can monitor key system parameters.

- GPS Lock Status: Only a few seconds of GPS data are needed to get the position. Normally the GroundTEM unit will always have GPS Lock.
- The instrument temperature should not exceed ~70˚C. A measurement will automatically stop if the temperature exceeds 75˚C.
- The HM and LM transmitter currents should be stable and within the green zone of the meters.
- The data curve plot displays the LM and HM data curves as they are recorded. Highlighted curves are the most recent data. Gray-curves are data from previous sequences. Red color indicates positive data points, blue color negative data points. They should be red.

7. Planning a survey

General

- Do not connect/disconnect plugs/cable while recording data.
- Do not connect/use damaged plugs or cables. For repair/replace options contact Guideline Geo or reseller. Minor damage on Tx loop can often be repaired with insulation tape.
- Do not connect plugs if the inside is wet or dirty.
- Besides field work, use the transport case for instrument transport/shipment.

Couplings/noise

TEM measurements close to man-made conductors will often be heavily distorted (non-usable), since the man-made conductors will produce a bias signal in the data due to a *coupling* to the transmitted EM-field. Potential noise sources could be power lines/cables, railways, fences, buildings, gas pipes, wind-turbines, cars etc. Safety distance to potential coupling sources strongly depends on the coupling source and the ground conductivity. To avoid non-usable data, keep a safety distance of a minimum of 100 m from the Tx loop side to potential coupling sources.

Measurement locations

To obtain 2D resistivity sections, the TEM measurement locations (stations) should be positioned on lines. The distance between the stations depends on mapping target, the lateral geological variations, etc. To obtain 3D or 2D horizontal resistivity grids, equally distributed TEM stations in the survey area is recommended.

Batteries charging

- Do not charge the batteries in ambient temperatures below 0°C.
- Do not charge the battery if the battery temperature is below 0°C.

Cold environment

Working in a cold environment (<0°C) be aware of:

- When bringing the GroundTEM unit from a cold outdoor to a warm inside: Do not power on the GroundTEM unit until it has reached the room temperature, due to condensation/short circuit risk.
- Cables and plugs become more fragile in a cold environment.
- The batteries are graded to an operational temperature down to -20°C.
- The battery capacity is reduced in a cold environment.

Warm environment

To prevent overheating the GroundTEM will automatically stop if the internal temperature exceeds 75°C. The internal temperature can be monitored in the GroundTEM App.

To prevent overheating, ensure good air flow around the metal cooling plate and provide shade for the GroundTEM unit.

Personal safety

For general person safety, we recommend a field crew of minimum two people.

8. Download data from GroundTEM units

The recording data is download/copied from the GroundTEM unit to a PC using the *TEM Data Manager* program. *GroundTEM Connect* program is available from Guideline Geo website (www.guidelinegeo.com). This section is written for version 1.1.0.

Connecting to GroundTEM Wi-Fi

The first step is connecting the *Local PC* to the Wi-Fi of the GroundTEM unit.

- Insert both batteries in the GroundTEM unit and turn it on.
- From the *Local PC* connect to GroundTEM Wi-Fi network. (see Figure 20, top)
  Wi-Fi name: GroundTEM####
  Password: GroundTEM

TEM Data Manager program

Next step is to use TEM Data Manager to download the data. The main program window is shown in Figure 20, bottom.

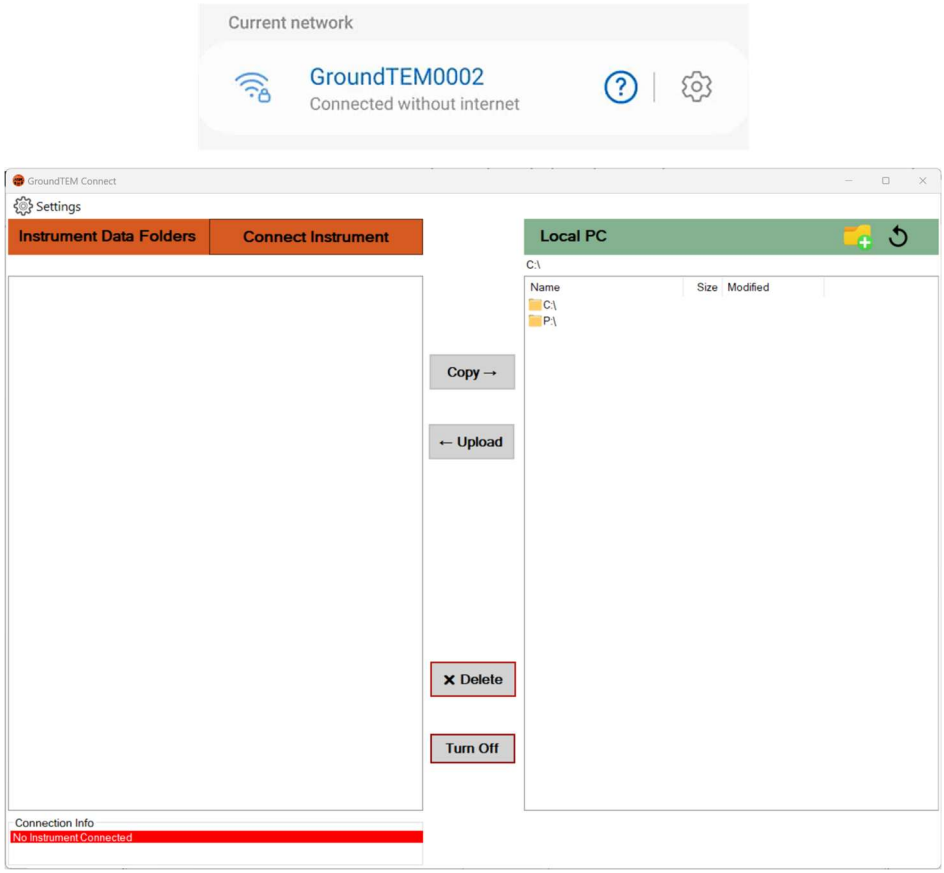

Figure 20. Top) Example of GroundTEM unit's Wi-Fi network name. Bottom) Main window of GroundTEM Connect data manager program (when not connected to the instrument).

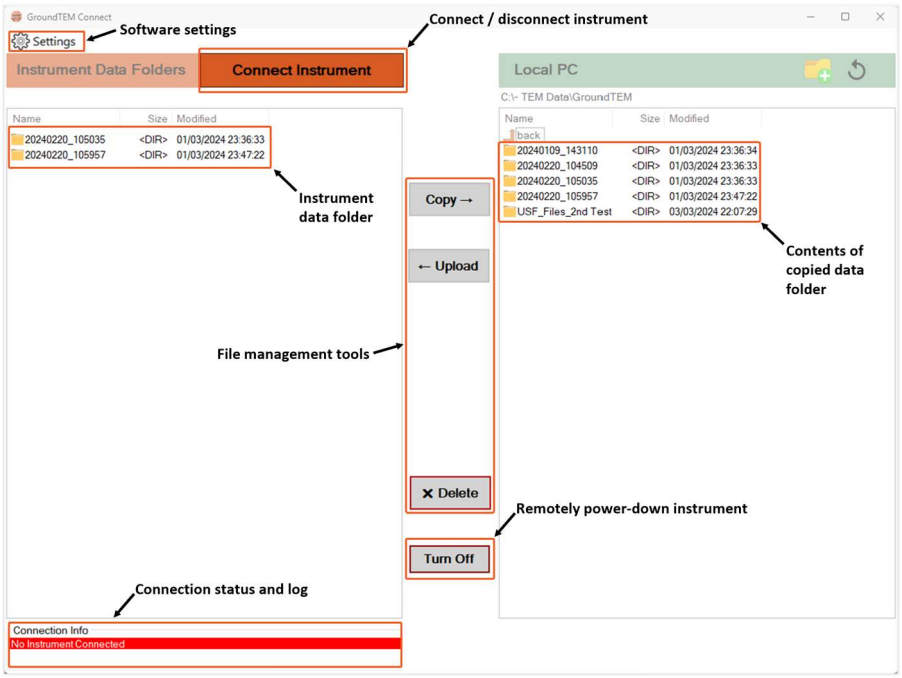

Figure 21. Steps for copying data from GroundTEM unit (after connecting to the instrument).

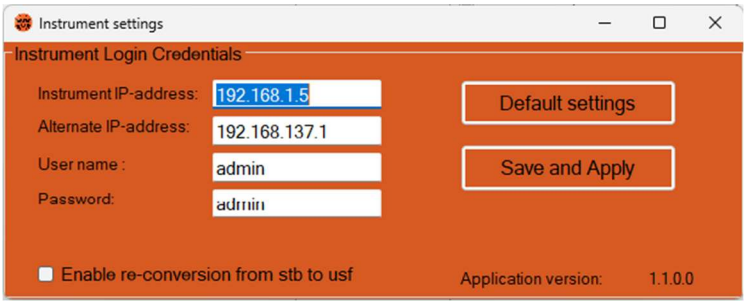

Figure 22. Settings for IP address and Login credential. Default settings are recommended.

To copy data from Instrument to Local PC

- Press *Connect to Instrument* to display the data folders on the GroundTEM unit (Figure 21).
  - The TEM data on the instrument is sorted in main folders named by (yyyy_mmdd)
  - Data from a station is placed in sub-folders with a date-time name (yyyy_mmdd_hhmmss) and should contain one stb-file and one stn-file.
- Select main- or sub-folder(s) to copy to Local PC and set a target folder on the Local PC.
- When copying, the binary stb-data files will be converted to USF-files. One USF-file per station will be created and all UFS-files in a Project will end up in a common UFS-file folder.
- Turn off the Instrument PC from the GroundTEM App before turning off the GroundTEM unit.

Note:

- Folders/files with date/time names are named using UCT-time (GPS date/time).
- User notes from the GroundTEM App grouped into one file in the USF-file folder.
- Before deleting data from the instrument, validate the data-files copied to Local PC.
- stb/stn-files on Local PC can be re-converted to USF-files, using the USF-STB button, with connection to the GroundTEM unit.

9. Troubleshooting - FAQ

GroundTEM App

Symptom/problem	Solution
The GroundTEM Wi-Fi does not show up on mobile device	Note that it takes a few minutes from turning on the GroundTEM unit until GroundTEM Wi-Fi is available. Check GroundTEM unit is on (both LED on). Check that Wi-Fi is turned on, at mobile device. Refresh available Wi-Fi list on mobile device. Move closer to the GroundTEM unit. Re-start the GroundTEM unit via the power button.
GroundTEM controller/GroundTEM Wi-Fi keep disconnecting	Make sure that the mobile data connection is turned off on the mobile device. Move closer to the GroundTEM unit. Turn off battery saving mode on mobile device.
Can't get GPS lock / GPS LED is not flashing	Note that it can take a few minutes from turning on the GroundTEM unit until GPS lock is obtained. Make sure that the GPS-antenna is pointing up and is not covered/shielded. If the mobile device can obtain a GPS-position, this position will be stored in the stn-data file and used if GPS data from GroundTEM unit is not available. At some locations GPS-signal can't be obtained. A GPS-position can then, manually, be associated with the data in the later data processing.
LM/HM current is not stable and/or not within the green zone of the of the meter	Stop the measurement(!): Check Tx loop connection to the GroundTEM unit (clean plugs if needed). Check batteries stage of change / replace batteries.
"Alternating sign pattern not detected" error	With the Rx coil placed inside the Tx loop It is fundamental that the primary field from the Tx loop, recorded in the Rx coil, has the correct alternating sign patten. If this is not the case this error will occur, and you should then check all connections. Very strong noise sources/couplings can cause disturbances in the sign patten. Try to relocate the measurement position. Constant "Alternating sign pattern not detected" errors from multiple locations can indicate general instrument errors and service might be needed.
Not able to stop a measurement	Only the mobile device that has stated a measurement can manually stop it again. A measurement will automatically stop when the selected time is reached.

The TEM signal looks very noisy	Check connections between receiver coil and lead-in cable and/or lead-in and GroundTEM unit. Note: A vary resistance sub-surface will produce a week signal, sometimes below the natural background noise level.
My data curves are negative (blue)	GroundTEM automatically detects and corrects the polarity of the TEM signal. If all data points above the noise level are blue (negative), you have properly placed the Rx coil outside the Rx coil (offset-configuration). To perform measurements in offset-configuration a dedicated protocol is needed. Contact Guideline Geo for support.
My data curve changes sign (blue and red) above the noise level	In a central loop configuration on a local 1D model negative data points cannot occur under normal circumstances. If part of the data, above the noise level, is negative, is it most likely caused by a strong noise/coupling source (data cannot be used) or induced polarization (IP) effect in the ground (review the literature of IP in TEM measurements).

9.1 How to get access to GroundTEM remotely

If neither of the above solves the issue, Guideline Geo support can help by accessing the unit remotely. To do this the GroundTEM unit must be connected to the internet, the flowchart in Figure 23 shows how the GroundTEM unit can go online. It requires a PC and a mobile hotspot.

Figure 23. Flowchart for how to put GroundTEM unit online.

First a PC must connect to the GroundTEM's Wi-Fi. Wi-Fi password is: GroundTEM

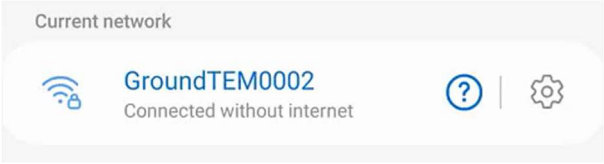

Figure 24. Example of GroundTEM unit's Wi-Fi name on Wi-Fi networks.

Then a remote desktop connection between the PC and the GroundTEM unit can be established. The password and username is: admin

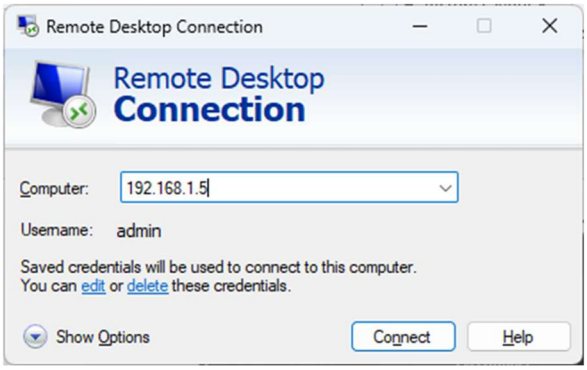

Figure 25. Remote Desktop Connection to GroundTEM unit. The password and username is admin. IP-address is 192.168.1.5

When connected via remote desktop, a Wi-Fi connection on the GroundTEM unit must be established to a router or a mobile hotspot. Verify the internet connection by opening a browser.

When connected to the internet, it is possible to get the GroundTEM unit accessible remotely by opening the TeamViewer program. The ID and password must be informed to the Guideline Geo employee.

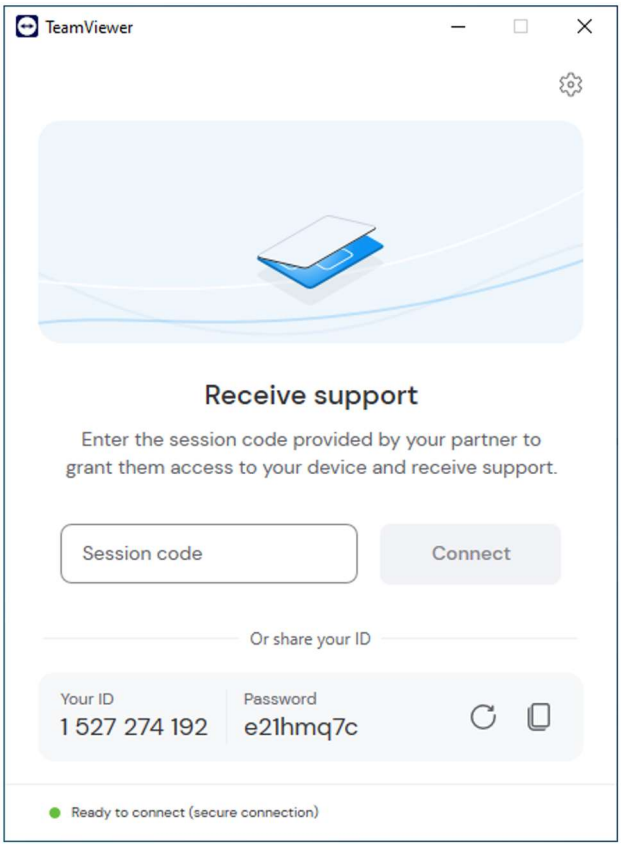

Figure 26. Example of what the TeamViewer ID and password should look like.

APPENDIX: How to handle GroundTEM data in SPIA and Workbench

In this appendix is a brief guide on how to import files to SPIA software, what the processing tools in SPIA software are, how to run a 1D inversion in SPIA and a LCI (Lateral Constraint Inversion) in Workbench, and finally how to interpret them.

1. Import to SPIA (SPIA version 3.8.0.0)

To import data in SPIA create *New project*, give it a name and save as .gdb (Figure 27) .

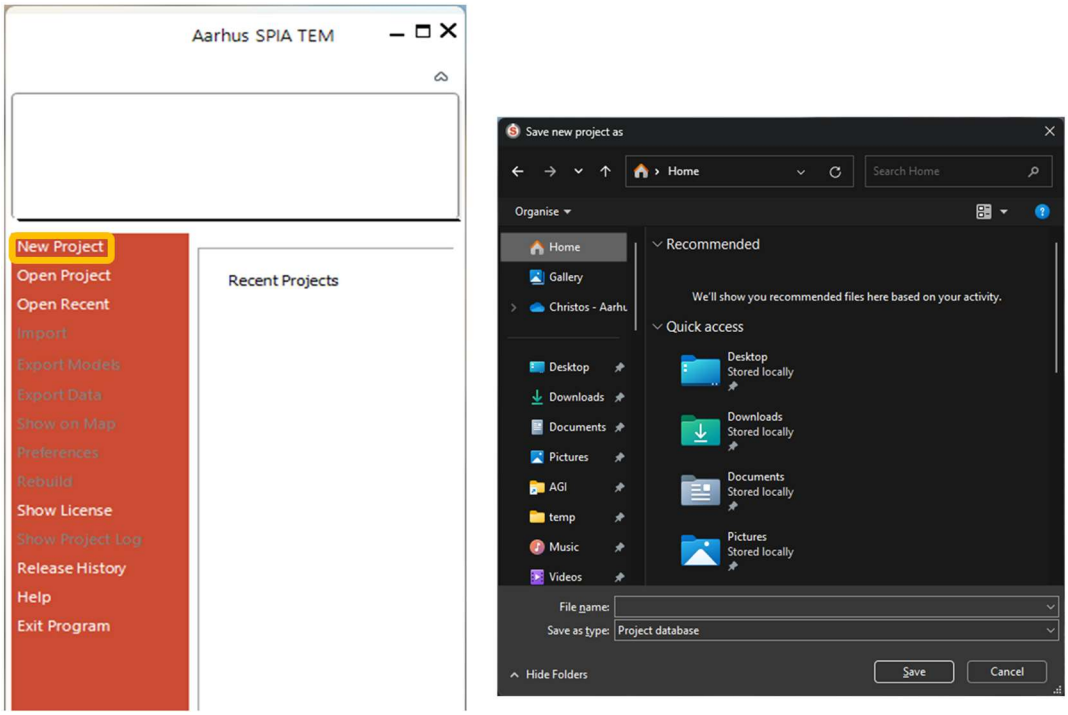

Figure 27. Steps to make a new project in SPIA software.

Next, select, *Import raw data in USF format*, click *Import*. In the *USF importer* select *Browse* to locate the data folders and select the USF files. Finish importing by pressing *Import* in the *USF Importer* (Figure 28).

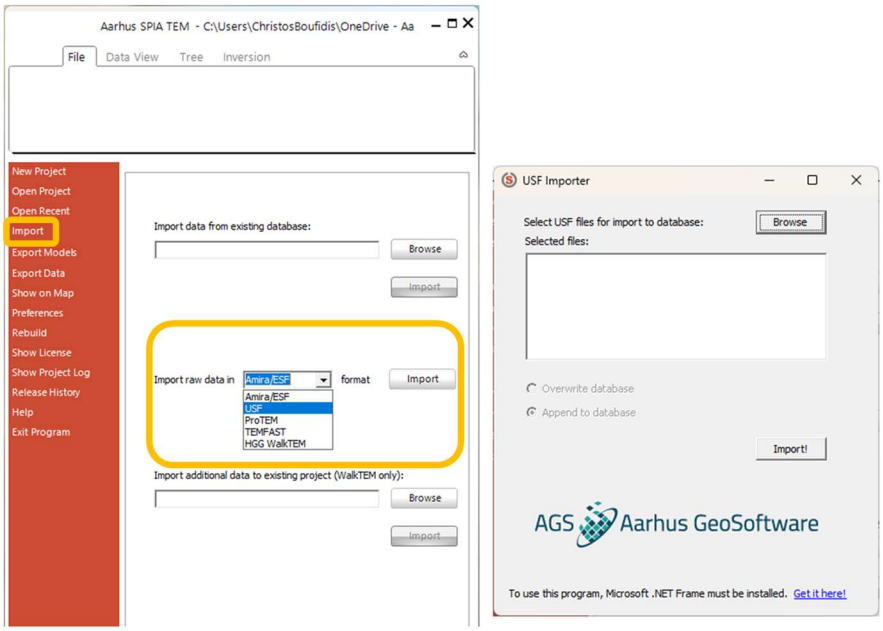

Figure 28. Data import. Select USF format and browse to locate the .usf files.

When importing is finished, the workspace will open. The interface of the SPIA environment is explained below.

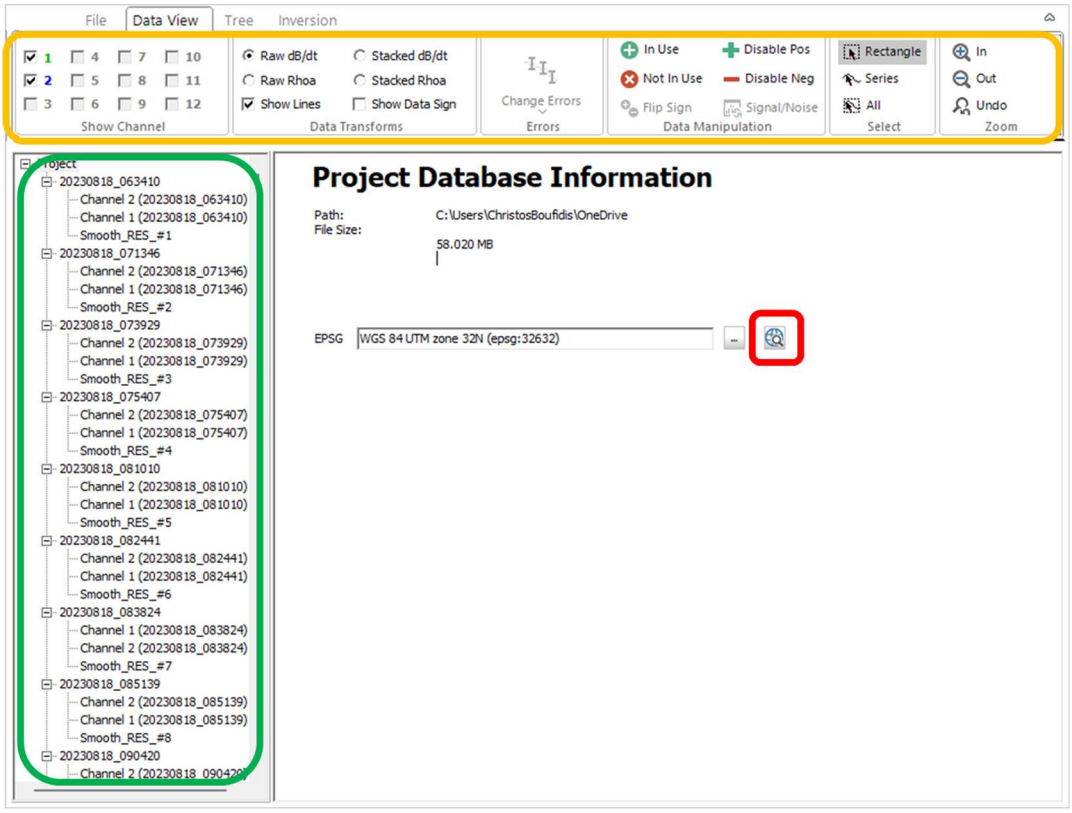

Figure 29. SPIA interface. On the left is the data tree (green) with the stations named based on the date and time of measurement. In yellow is the Data view ribbon with options and tools for data processing.

The data tree node is on the left (Figure 29, green shape), with each sounding name based on the date and time. On each sounding there are sub-nodes for each channel (Channel 1 – HM and Channel 2 – LM), as well as completed inversions (i.e., smooth, layered & blocky). Data view ribbon (Figure 29, yellow shape) contains the necessary tools for the data processing. Particularly:

- *Show Channel* tab: Select which channels (from 1 & 2) will be shown.
- *Data Transforms* tab: Switch between Raw dB/dt and Stacked dB/dt. Display decays as lines (or only points) and their sign.
- *Errors* tab: Percentage of standard deviation (standard is 3% - not recommended to change).
- *Data Manipulation* tab: Enable or disable gate times from each channel.
    - Alternative options are the following keyboard shortcuts:
        - In use: Alt + A
        - Not in use: Alt + Q
- *Select* tab: Different options for how to select data.
- *Zoom* tab: Zoom tool for more detailed processing.

By clicking on the globe icon (red shape) a tab opens in the web browser showing a map with the locations of all the soundings in the project.

1.1 Processing - SPIA software

Processing

GroundTEM data processing requires to be aware of outlier gate that differ significantly from a smooth data decay and make them inactive (*Not In Use*). To begin processing, click either on the sounding name or on one of the Channels (Figure 30). Doing the latter one helps to do more detailed and precise processing.

Processing Tips

When going from Raw data to Average data, the applied filters automatically remove outliers that are out of the filters' range and that may remove data that can be usable. In that sense, it is advised to process data when they are plotted in Raw dB/dt or Raw Resistivity. Doing so, it's easier to determine if an outlying gate time should be active or inactive.

Removing outliers may include the first 3 gate times for LM and the first 4 gate times for HM (i.e., in high resistive areas the primary field is still "visible" in first time gates in each moment). Similarly, overlapping gate times between LM and HM is recommended to make inactive to improve Depth of Investigation (DOI) estimation.

Lastly, keyboard shortcuts are quite useful for data processing. Use the mouse to select gate time points and then Alt + Q to make them inactive ("Not In Use") or Alt + A to make them active ("In Use").

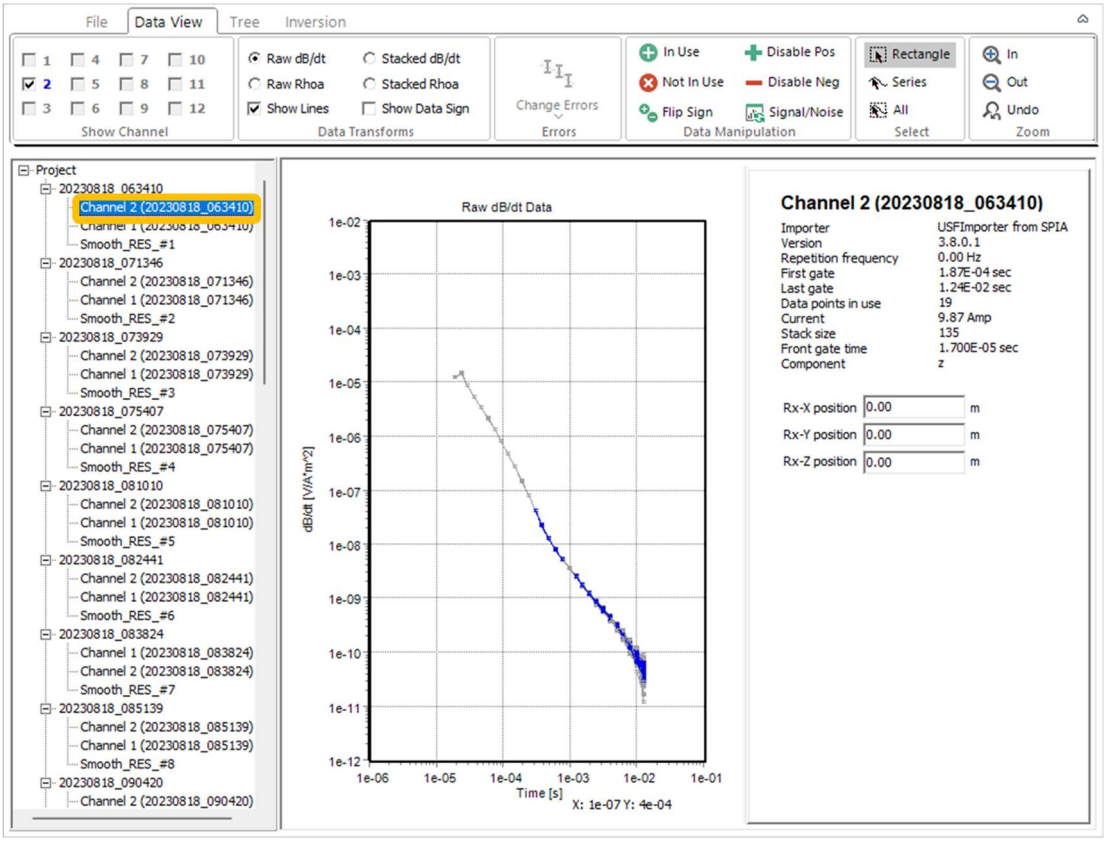

Figure 30. Processing window of SPIA. Select sounding to see both channels at once.

1.2 Inversion - SPIA software

Inversion ribbon (Figure 31) provides both standard and advanced inversion.

Standard Inversion

Particularly, default options are when one clicks on the "Standard Inversion" tab, on the left of the ribbon. When stepping on the sounding name, click on "Run" to invert only the specific sounding or "Run all" to run inversion for all the soundings in the project. When the inversion is completed, two types of inversion models will appear, Smooth and Layered by default. The smoothness (constraints' strength) of the inversion can be decided by the scroll down bar on the left.

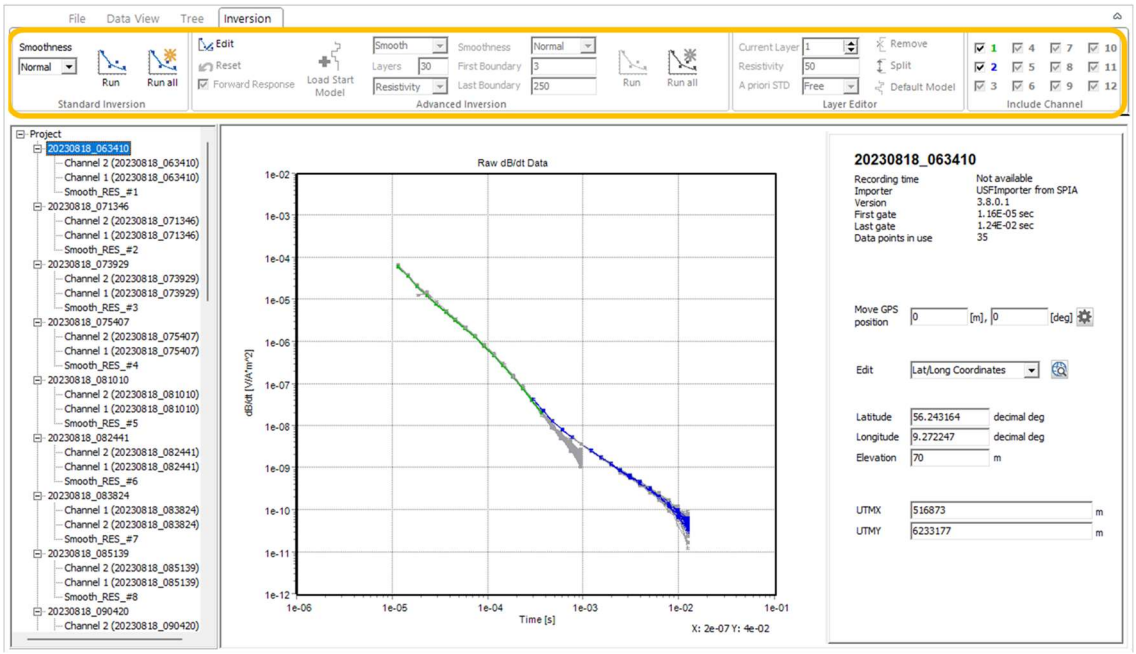

Figure 31. Inversion ribbon. Default options for inversion is presented on the left of the ribbon in "Standard Inversion" tab.

Advanced Inversion

For the advanced inversion, the *Edit* option is available in *Advanced Inversion* tab, when the sounding is selected (Figure 32). When the inversion settings are being set up manually, several options can be modified i.e., smoothness, number of layers and more (Figure 33).

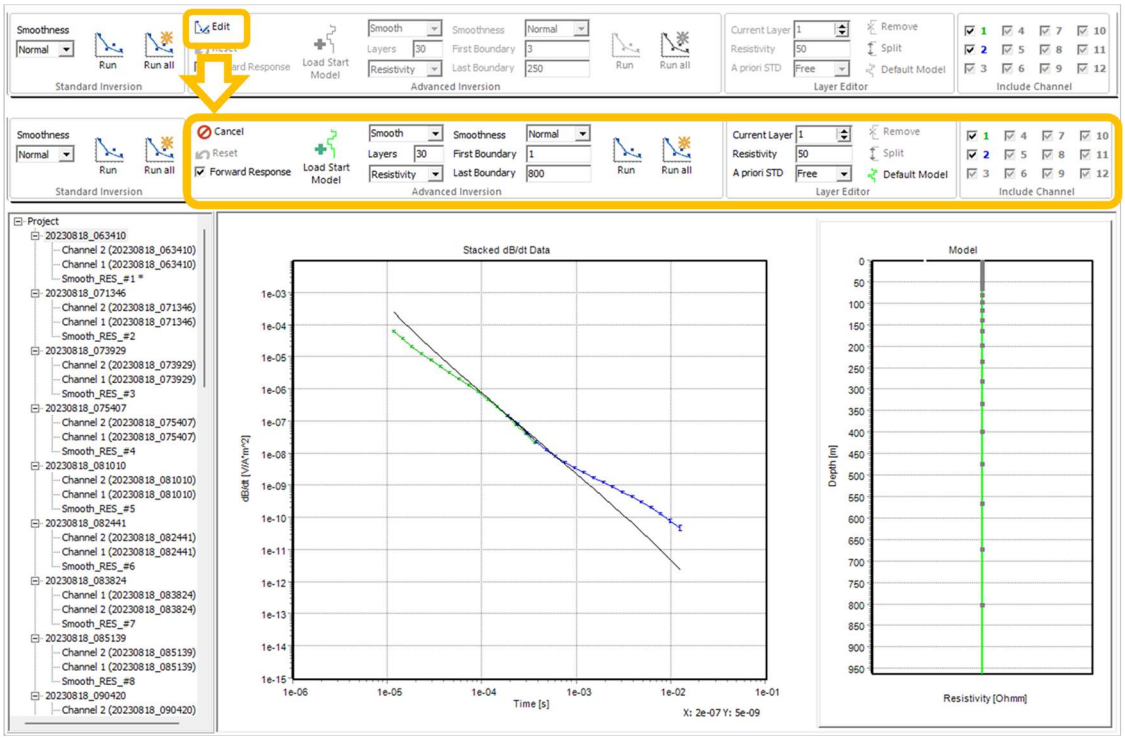

Figure 32. Manually edited inversion. Click on the "Edit" option available in the "Advanced Inversion" tab, and the different options for advanced inversion become available.

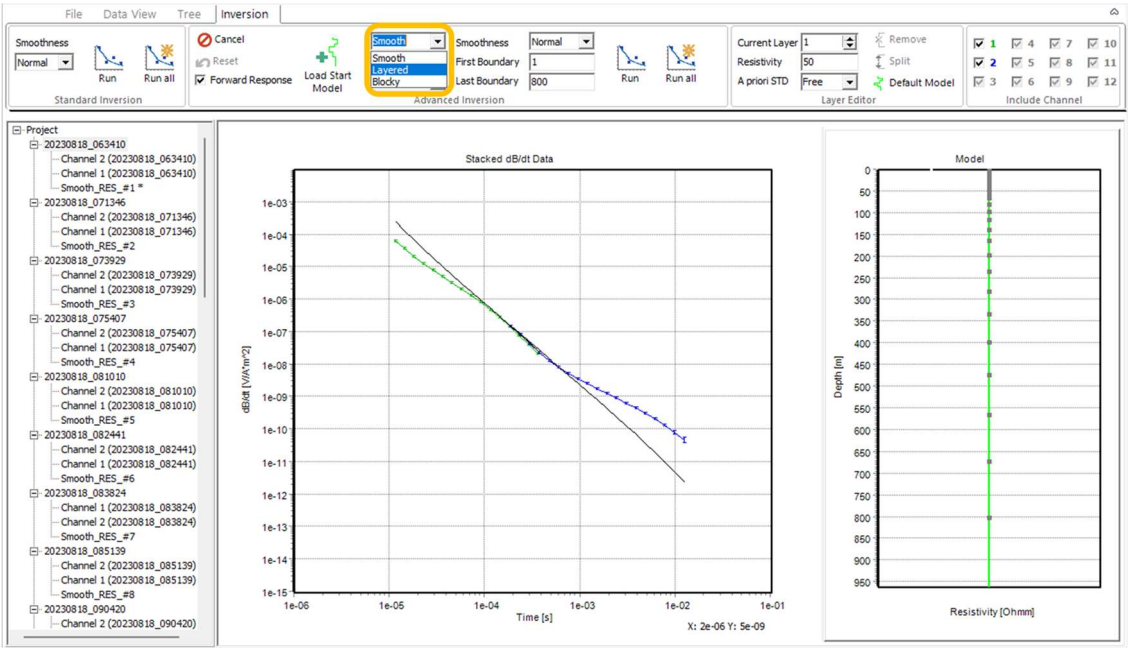

Figure 33. Inversion options for advanced inversion, such as Smooth, Layered and Blocky.

Inversion Results

An example of how the inversion results is displayed is shown in Figure 34. The model's graph can be seen on the right of the screen while the option of displaying the results as a table is available in the "View" section. On the left of the ribbon is important information about the model (DOI, Layers and Data Residual). The red line indicates Resistivity for each layer and the green horizontal line shows the Depth of Investigation (DOI).

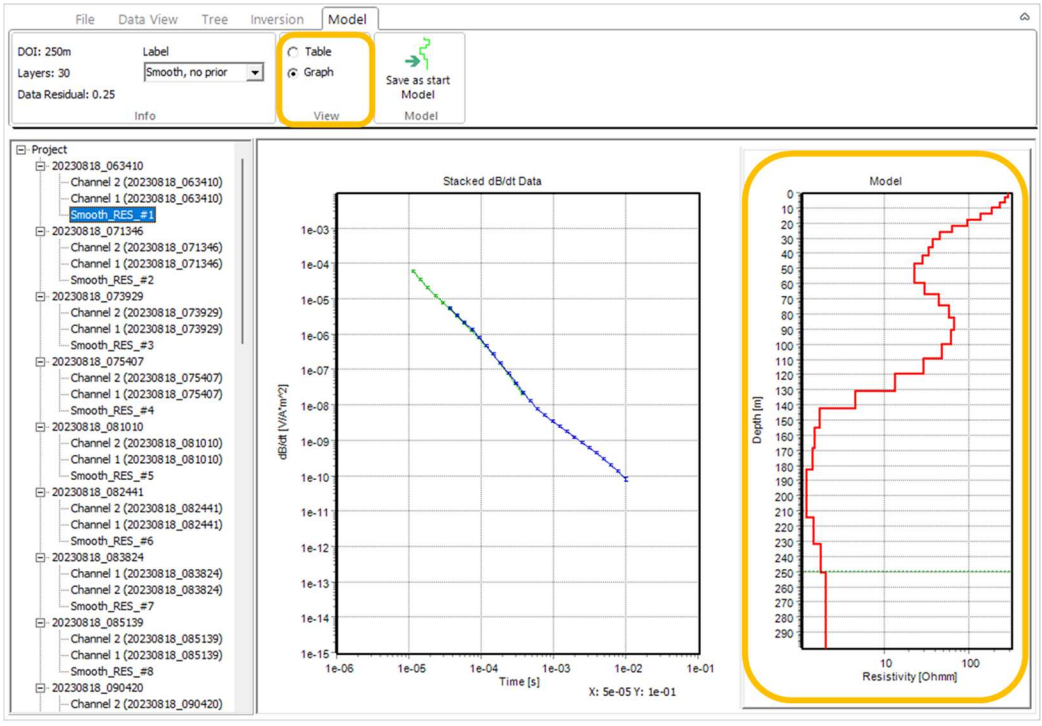

Figure 34. Inversion results display. Results are shown either as a graph (like the example above) or as a table.

2. Import GroundTEM SPIA models in Workbench

Before importing GroundTEM models to Workbench it is required to process the data and run inversions of all relevant stations in the SPIA software. Then, a few steps are required to export the models from SPIA before they can be imported in Workbench.

Export from SPIA

To export models from SPIA, change the label on the "Model" ribbon, from i.e., "Smooth, no prior" to "Final, Smooth, No prior". Adding this label will automatically put a small star in the inversion result under the sounding in the data tree node on the left (Figure 35). That step is useful to distinguish the preferable model, between several inversions that may have been tried for each sounding, in the import step in Workbench.

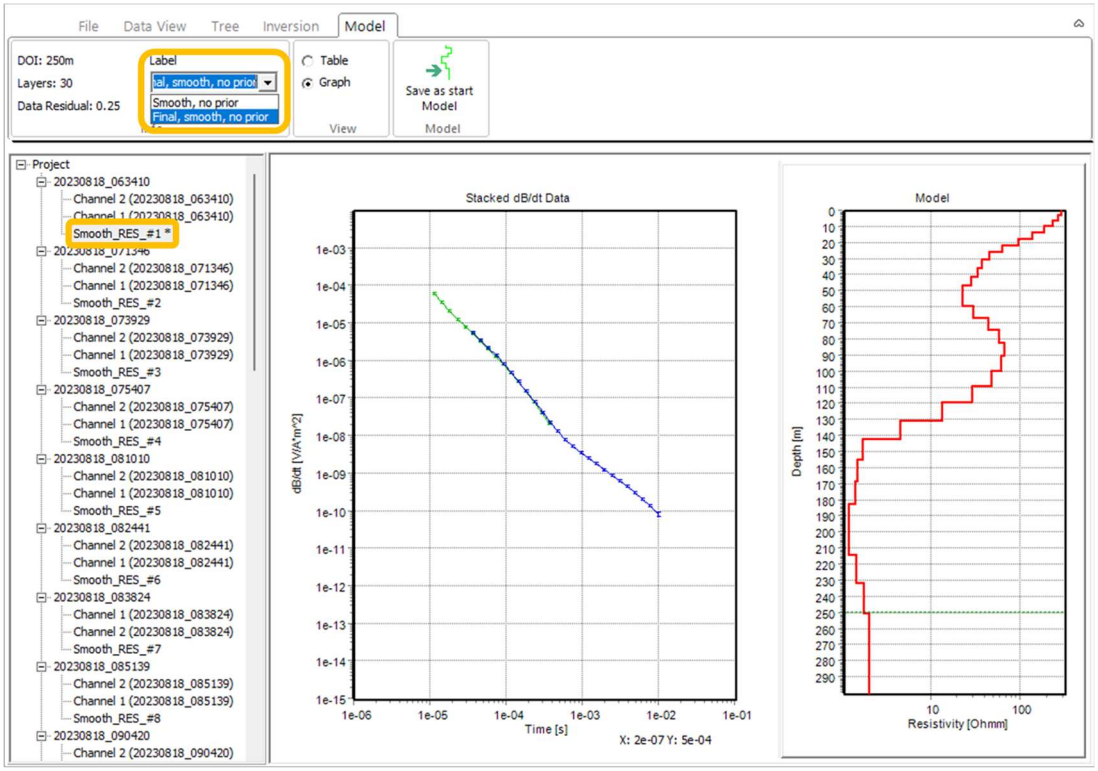

Figure 35. Export models by marking them with the label "Final" in model ribbon.

After marking the preferred models and under *File* ribbon, the *Export Models* options can be found. There, select the ones marked with the label *Final*.

Import in Workbench

In Workbench, in *Database Explorer* click on *Geophysical data* and then on *Open Database* in the *Database* ribbon (Figure 36). Find the .gdb database file from SPIA and select it. The message in Figure 36 will appear next and click *Yes* to proceed.

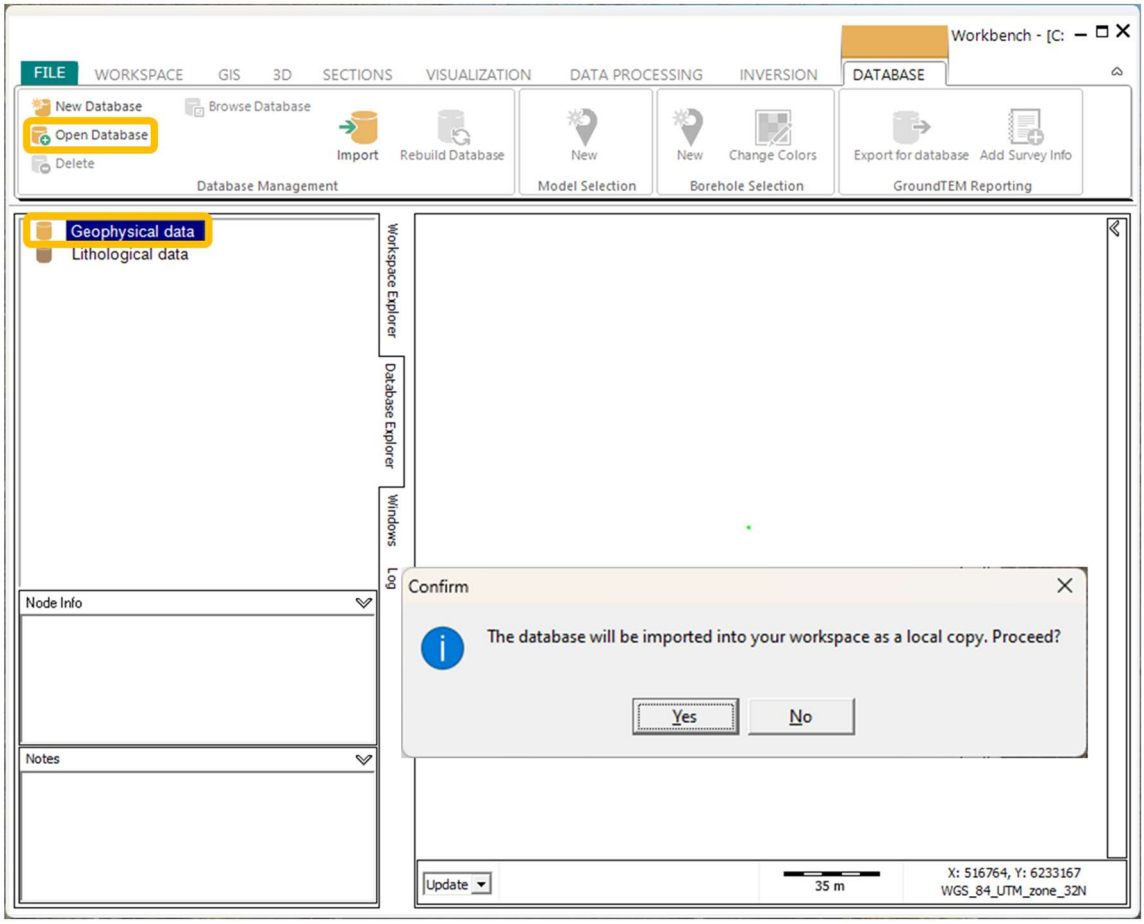

Figure 36. Import .gdb database from SPIA into Workbench. A confirmation window will pop up to complete the import in Workbench.

The database will appear in the *Database explorer* and a *Model selection* can be made. To do so, step on the imported .gdb file and then click on the *New* in the *Model Selection* tab (see Figure 37).

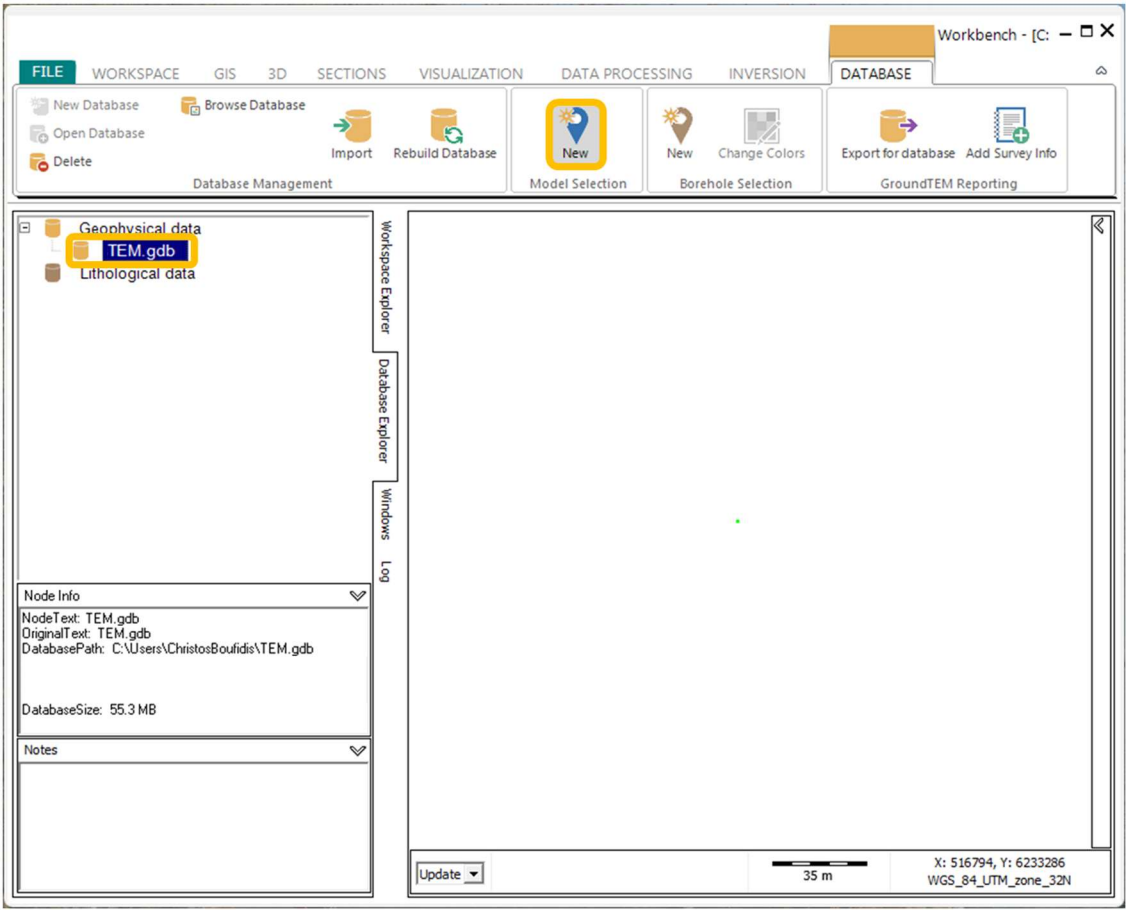

Figure 37. Create a "New" model selection after importing the GroundTEM database from SPIA.

Select the preferred database (Figure 37) and in *New Model Selection* choose the *Select edition* option (Figure 38). Then click *Next* to go to *UTM's and Dates* selection, click *Next* if no preference has been given (Figure 39) and lastly, select which inversions will be used (the ones marked as *Final* or any of the other ones). The displayed inversions are the ones that are exported from SPIA after labelling them with the *Final* label. Give a name to the model selection and click *Ok* to complete the process of importing.

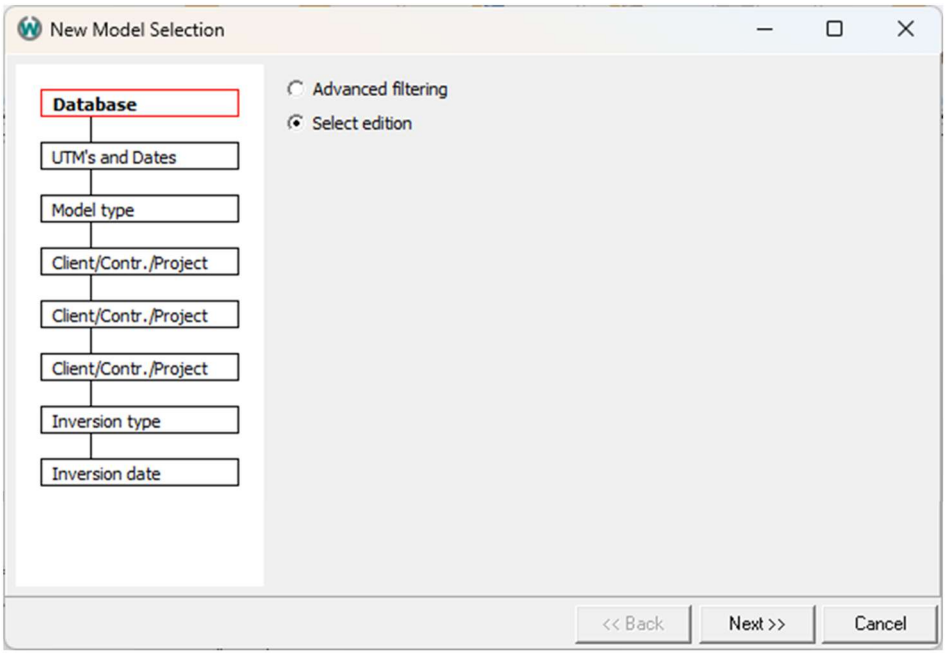

Figure 38. New model selection window where the Select edition option must be selected.

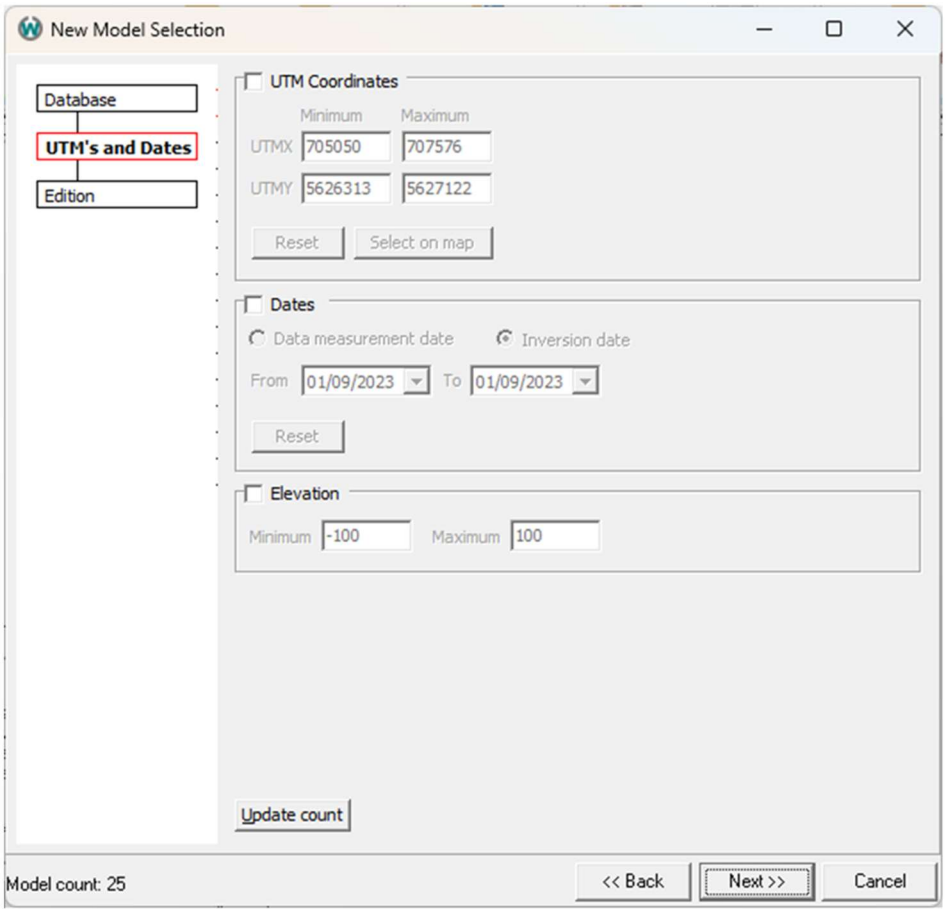

Figure 39. Specify UTM coordinates, Date or Elevation. Alternatively, select Next to proceed with the model selection.

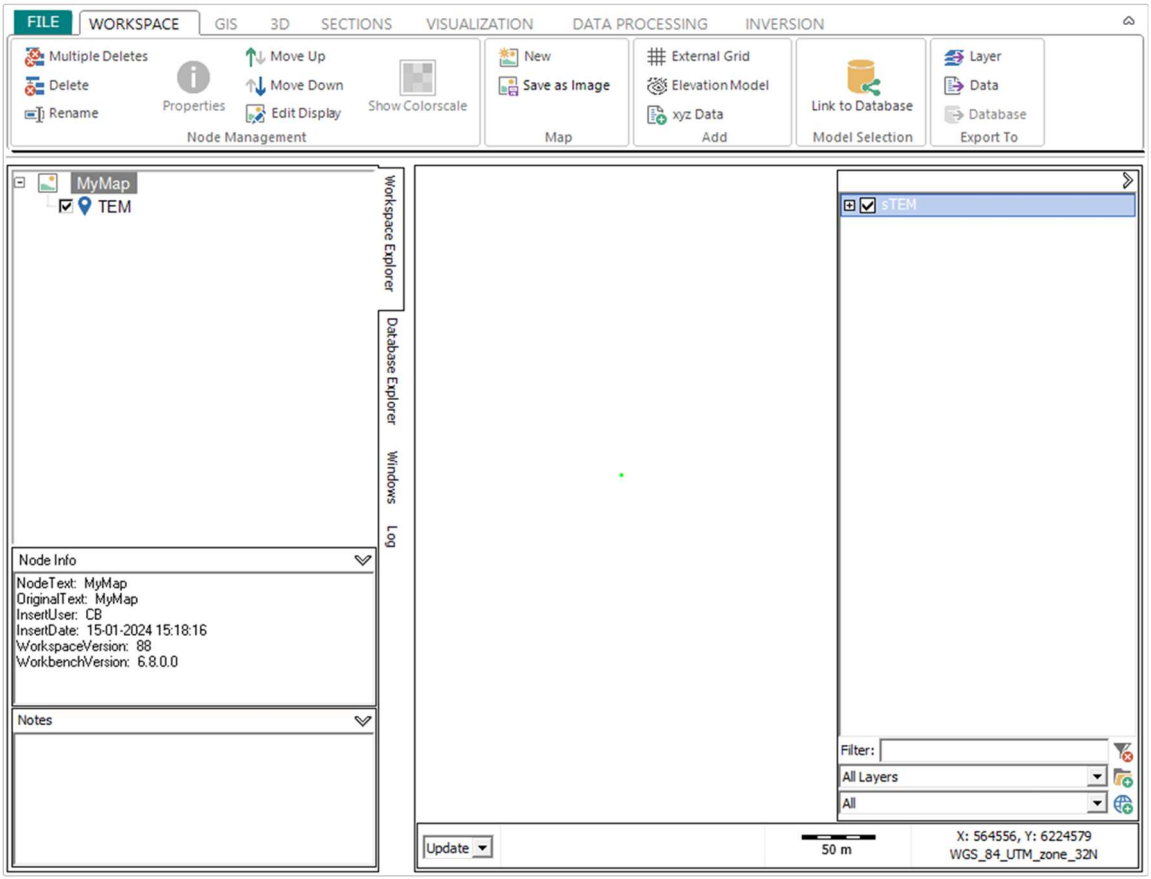

Figure 40. Model selection appears in Workspace explorer, on the left, as well as in the right in the GIS window.

2.1 LCI inversion of GroundTEM data in Workbench

GroundTEM data can be inverted in Workbench with a Lateral Constraint Inversion (LCI). To achieve that, continue from the step shown on Figure 41 and use the *Data* option in *Create New* tab under *Data Processing* ribbon.

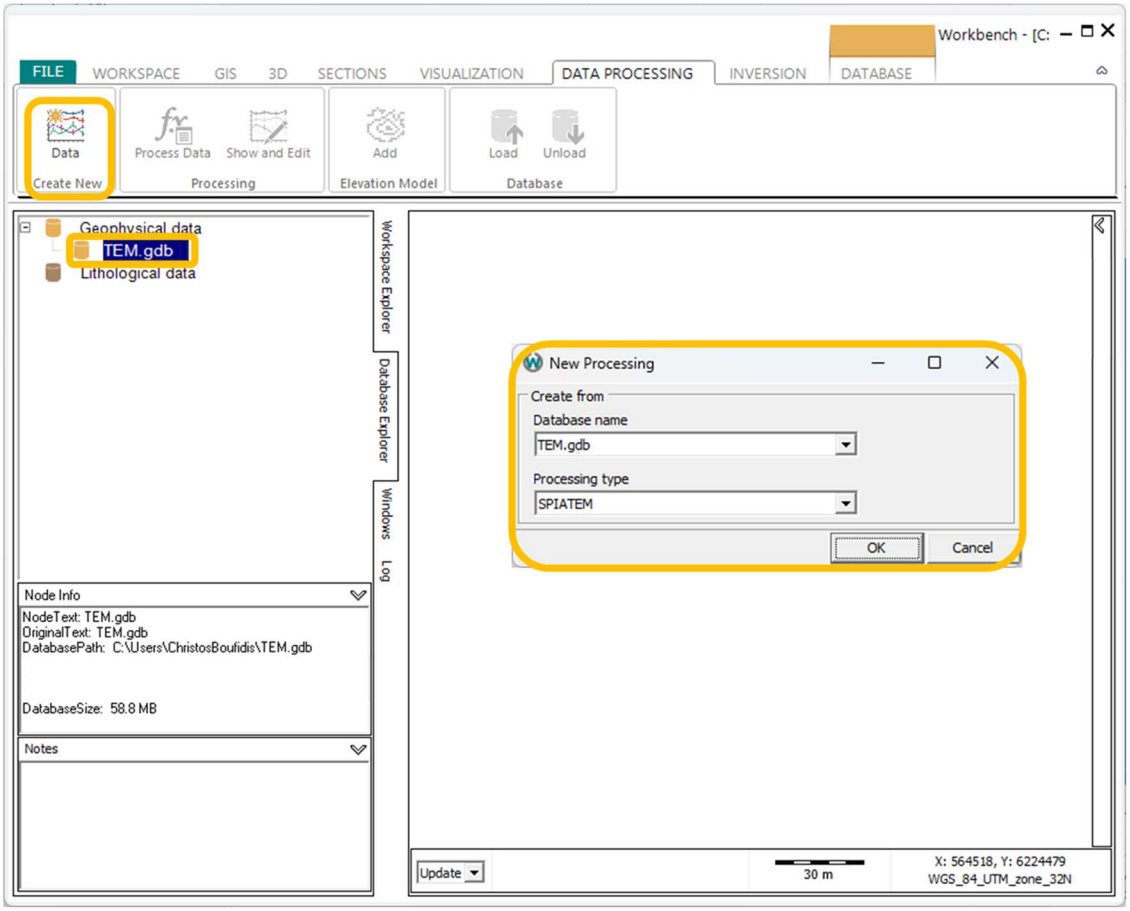

Figure 41. Steps for how to make a new processing node for GroundTEM data before the LCI inversion.

Afterwards, select dataset in *Dataset Selector* and finally give a name for the new processing. The processing node will appear in the data node and then a LCI inversion can be established (Figure 42).

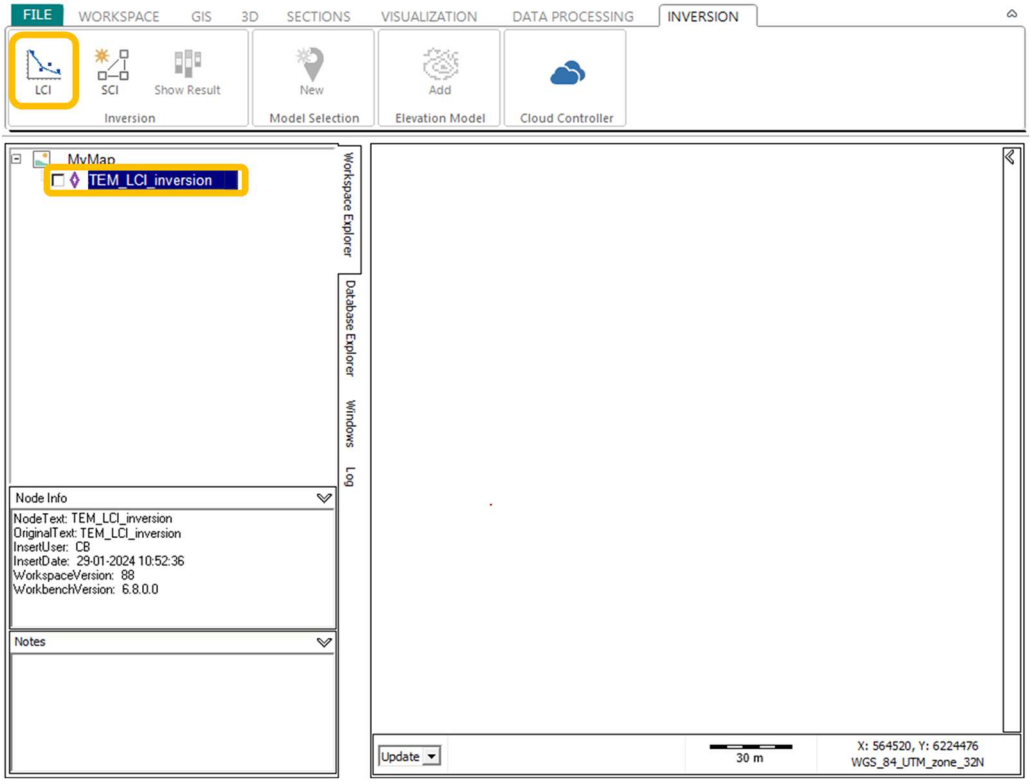

Figure 42. GroundTEM data processing and the LCI inversion has been selected.

2.2 Interpretation – Aarhus Workbench software

When data has been imported to Workbench, either as a model or as raw data and inverted in Workbench itself, it can be displayed in different ways. Below is a brief description of the typical ways. Pressing *F1* under *Visualization tab* is a direct link to the wiki page of Workbench for how to make each of these visualizations.

Quality maps- Number of Data, Data Residual and Depth of Investigation

Quality maps can provide information regarding the data residual, the depth of investigation (DOI) and the number of data points. The values shown as data residual have been normalized with the data standard deviation. Thus, values below one translates to a fit within one standard deviation. The second one shows the estimated DOI for each inversion model and the latter one holds the amount of data, indicating the S/N ratio on each sounding.

Mean Resistivity Maps

With Mean Resistivity Maps, horizontal slices all through the study area are being created. They have uniform specified intervals, and their starting point can be the topography of the area (depth) or the distance from the sea level (elevation). Mean resistivity values for every horizontal slice are calculated from each model and interpolated to a regular grid.

Section/Profiles

Profiles are termed the vertical slices that have been picked through the study area. On each profile information can be added, such as inversion models, borehole data, elevation etc.

Inside back cover

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