TEMcompany

sTEM

User Guide

Ver.1.1.1

TEMcompany
Value groundwater assets

TABLE OF CONTENTS

1. INTRODUCTION

1.1 What does the user manual contain

This is a user manual for the sTEM instrument. Sections 2 and 3 have a description of the different components of a sTEM system. Operation of the sTEM system in the field, is described in section 4 and 5. sTEM controller 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 sTEM instrument quick operation guide is shown in Figure 1, which is also embedded in the in the sTEM case.

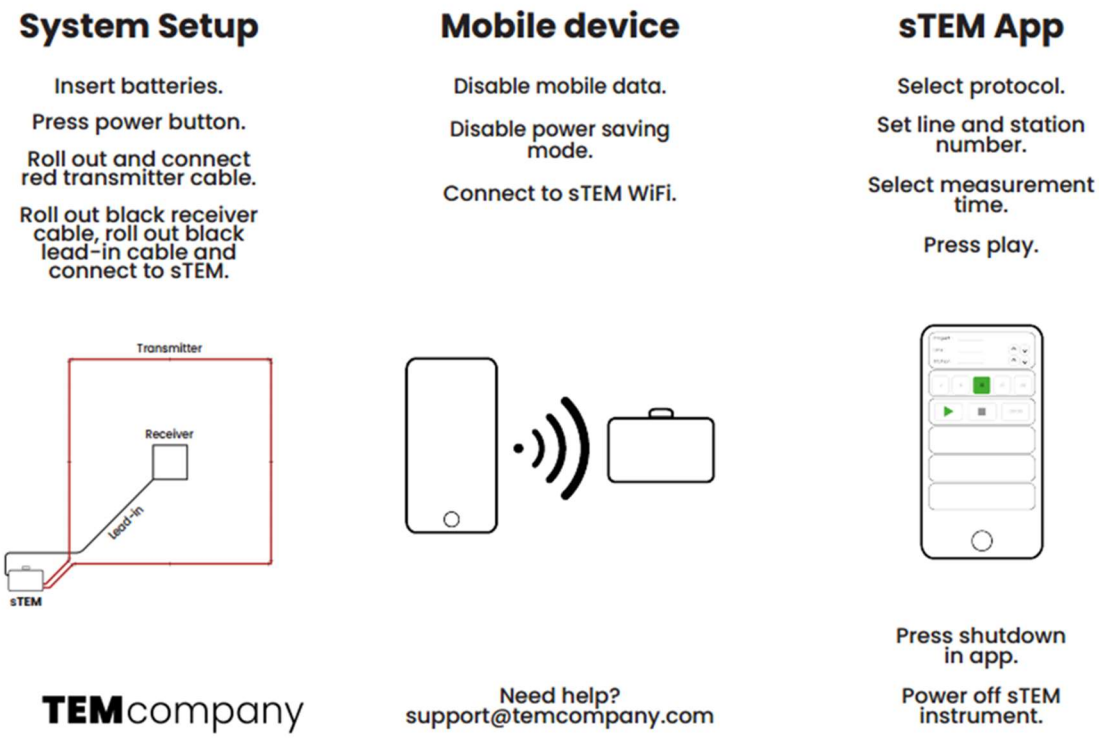

Figure 1. Quick sTEM operation guide

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.

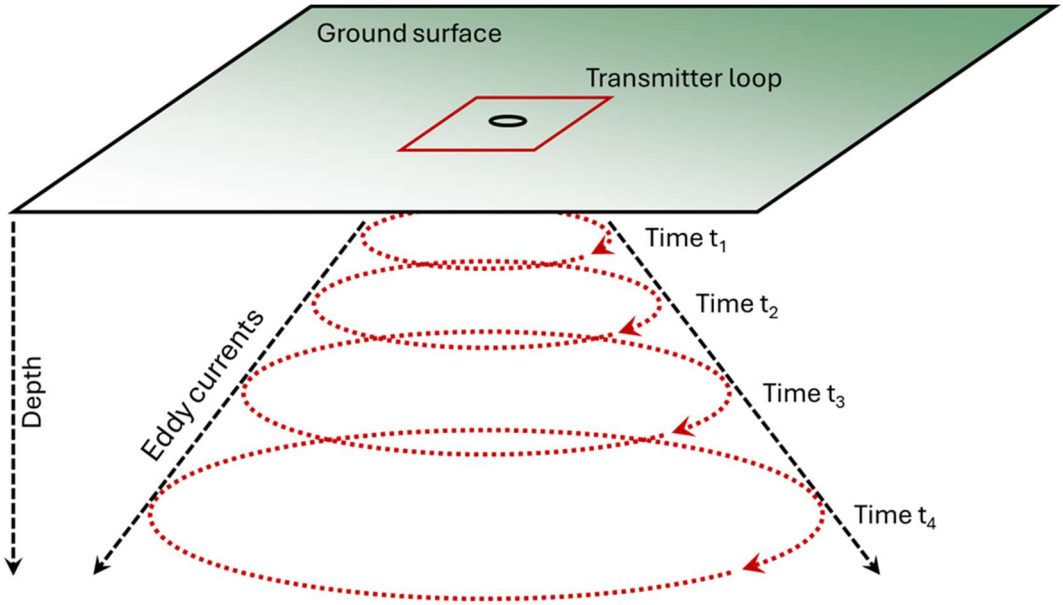

Figure 2.Principal sketch of the TEM method

2. THE STEM SYSTEM - COMPONENTS

Figure 3 shows the main components of a sTEM system.

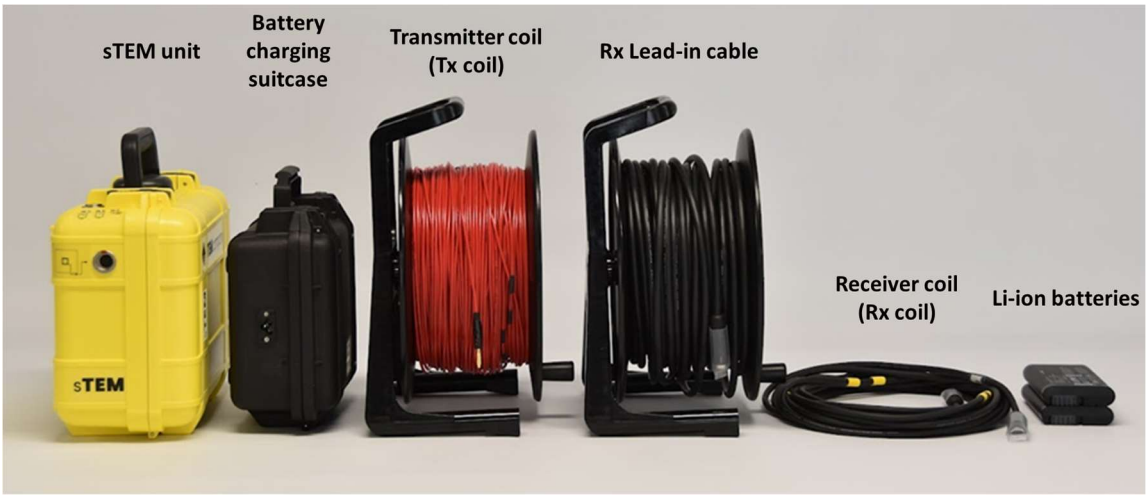

Figure 3. Main components of the sTEM system

sTEM 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 coil)

- Size options: 20x20 m, 40x40 m, 80 x 80 m.
- Black corner markers on cable to form a square loop (see Figure 7).

Receiver coil (Rx coil)

- Size options: 3x3, 5x5 m.
- Yellow corner markers on cable to form a square loop (see Figure 3).

Rx lead-in cable

- Cable for connecting Rx coil to sTEM unit yellow markers where lead-in crosses Tx coil.

Battery

- Li-ion batteries (two Li-on batteries are needed).
- 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 an 40x40 m TX loop setup including sTEM unit is approximately 19.5 kg (excl. battery charging suitcase).

3. THE STEMPROFILER – COMPONENTS

Figure 4 shows the main components of a sTEMprofiler.

Figure 4. Main components of the sTEM profiler system, The total system weight for a sTEM profiler setup including sTEM unit is approximately 19.5 kg (excl. battery charging suitcase).

sTEM 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 coil)

- Size options: 3x3
- Red and blue markers indicating the orientation of the coil (see Figure 13).

Receiver coil (Rx coil)

- Size options: 3x3
- Red and blue 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.
- 4 pairs of white tubes for each frame (16 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.

4. STEM – FIELD OPERATION GUIDE

A field crew of two people is recommended to operate the sTEM 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 sTEM unit.
2. Layout of the Tx coil.
3. Layout of Rx coil and Rx lead-in cable.
4. Operate the app to collect data.
5. De-mobilize the system.

4.1 Powering on the sTEM unit

To turn on the sTEM unit:

- Insert two RRC 2054-2 batteries in the battery slots in the sTEM unit (see Figure 7).
- 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.

The third LED light is GPS lock indicator (see Figure 7).

- 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 sTEM unit before rolling out the cables.
- 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.

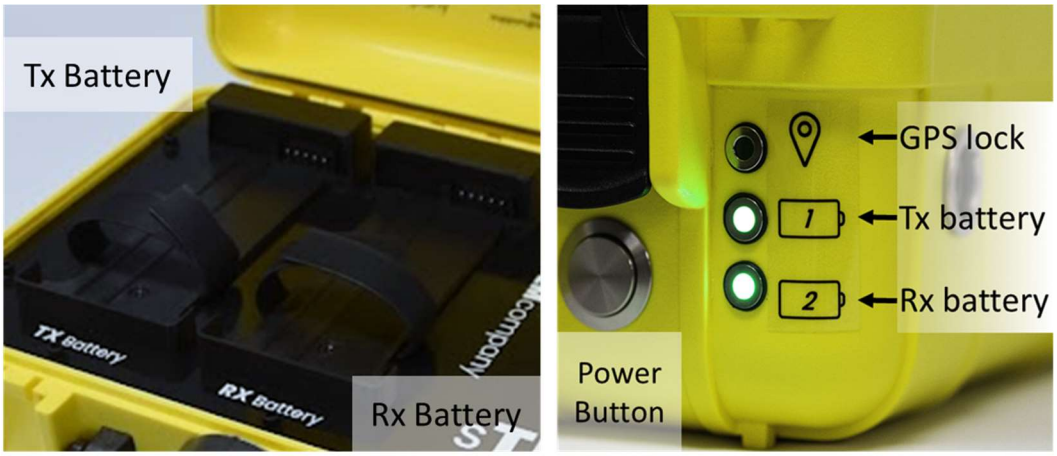

Figure 5. sTEM unit. Battery slots and battery LED lights when batteries are inserted.

4.2 Layout of the transmitter coil

Figure 6 show a sTEM layout with a 40x40 m Tx coil and a 3x3 m Rx coil. Different coil sizes follow the same layout plan, with some adjustment in the case of 80x80 m Tx coil. The Tx- and Rx-cables have corner markers, additionally the Tx-cables have center markers.

40x40 m & 20x20 m Tx coil

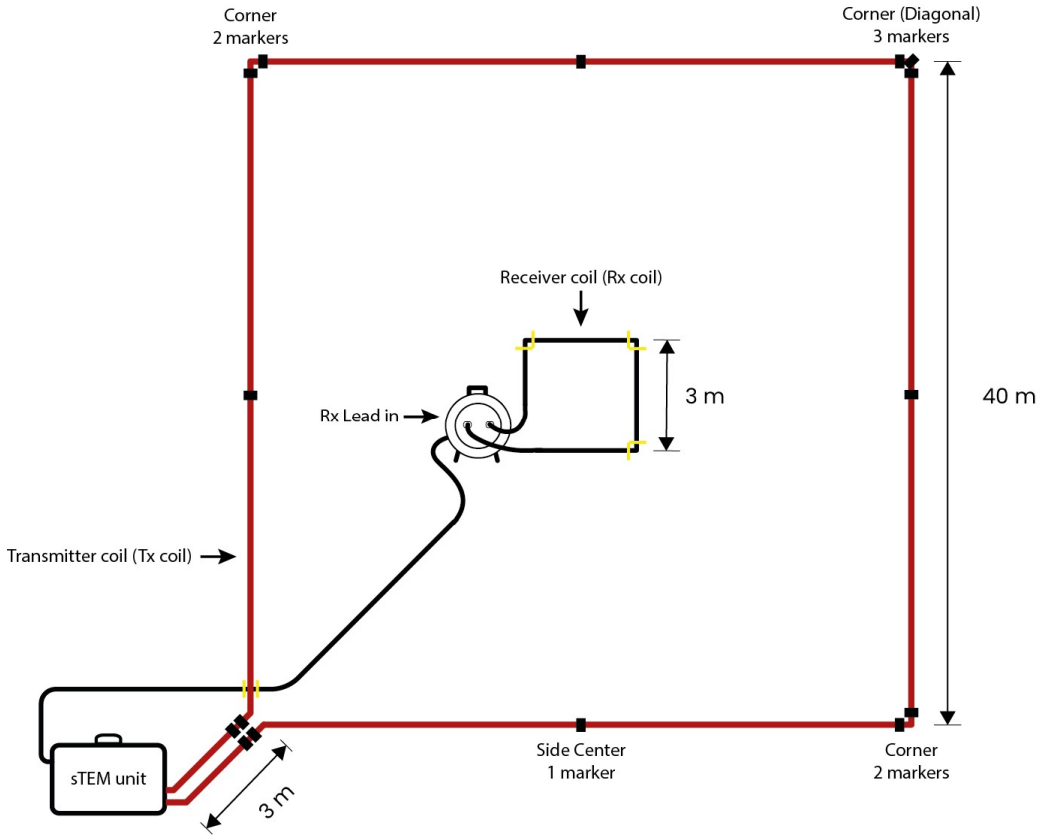

Figure 6. Example sTEM system layout with a 40x40 m Tx coil and 3x3 m Rx coil. The 20x20 m Tx coil only has corner markers

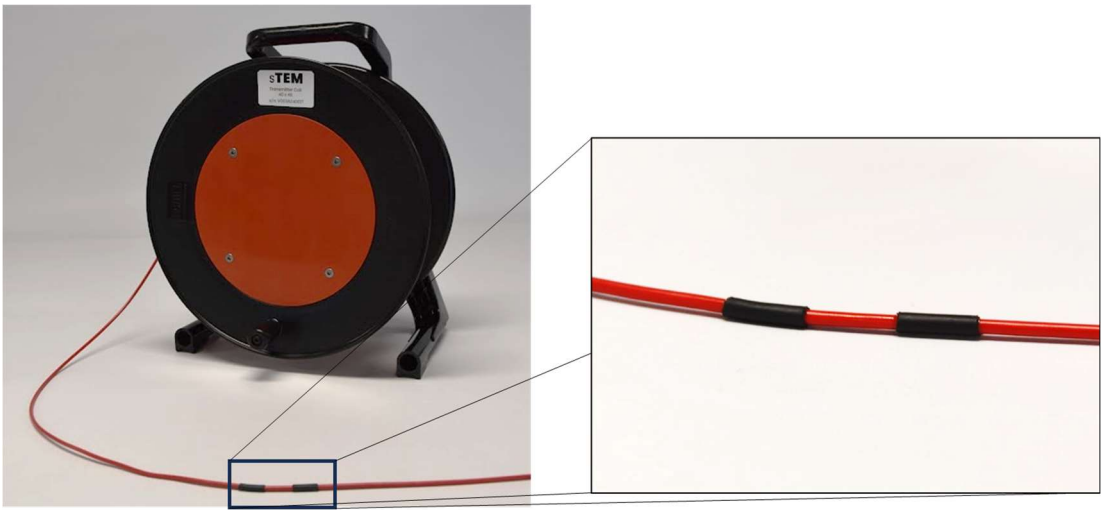

Figure 7. Tx coil corner marker.

Layout the Tx coil

- Pick a corner position and roll out the first ~3 m of the Tx coil 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 coil 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 center marker on each side.
    - The 20 x 20 m Tx coil only has corner markers and does not have center markers on each side.
- If the two sets of markers do not meet up in the corner where the sTEM unit is, adjust the Tx coil accordingly. Minor inaccuracies (<1 m off) are acceptable and may be adjusted by a gently pull in the cable to make the markers to meet.
- Move the sTEM unit the ~3 m outside the Tx coil (see Figure 6) and connect the Tx coil via the banana plugs to the sTEM unit (Figure 8). The connection order of the two banana plugs is irrelevant.

Figure 8. sTEM banana plugs. Connect Tx coil 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 sTEM unit will make it easier to position the Rx coil in the center.
- Tx coil area should match the nominal Tx coil area within a few percentages.

80 x 80 m Tx coil

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 9). Follow the colored connectors in the beginning and at the end of each cable, for easier laying out.

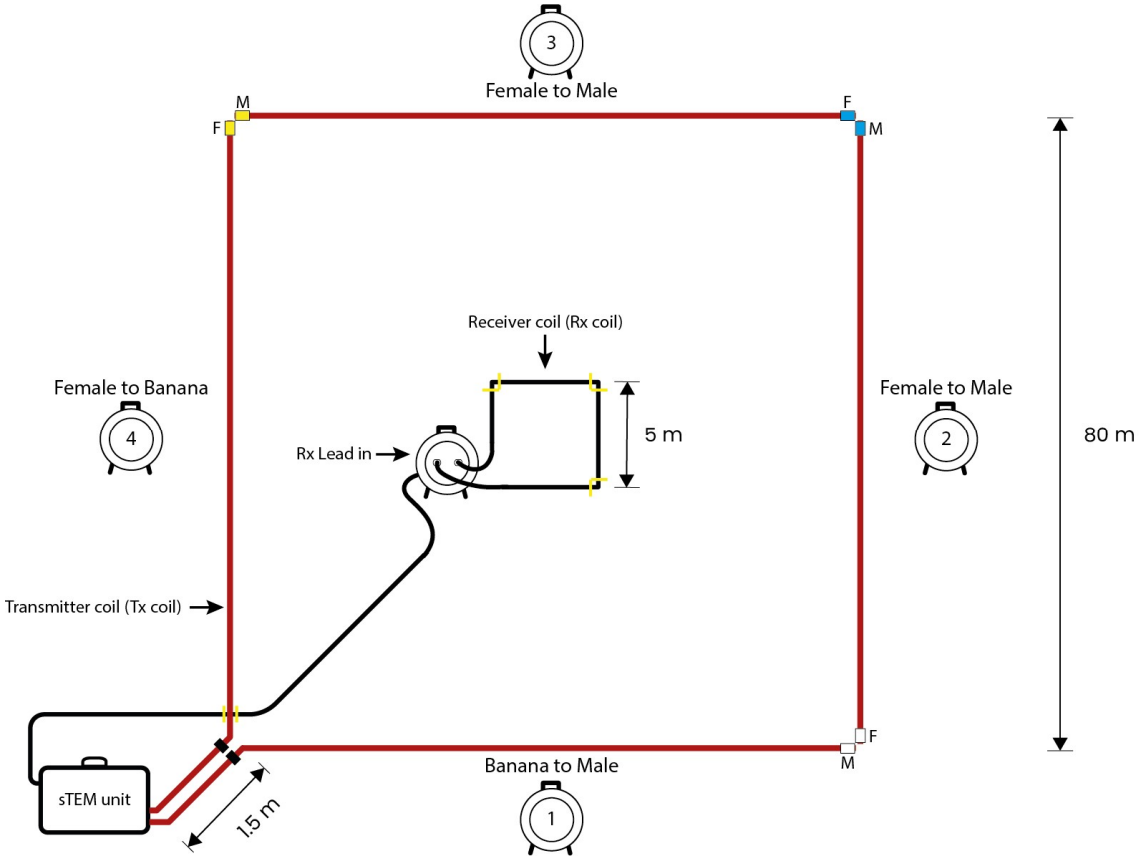

Figure 9. Example sTEM system layout with 80x80 m Tx coil and 5x5 m Rx coil.

4.3 Layout receiver coil and lead-in

The Rx lead-in cable is marked with yellow markers to provide the distance from the home Tx coil corner to first Rx coil corner (see Figure 10). To layout the RX lead-in and Rx coil do:

- 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 6/Figure 9)
- Layout the Rx coil in a square as shown in Figure 6/Figure 9 and connect it to the Rx lead-in cable drum (see Figure 10).
- In the home corner, connect the RX lead-in cable to the sTEM unit. The extra RX lead-in cable should be placed as in Figure 6/Figure 9, crossing the Tx-cable perpendicular.

Note

- Avoid additional cable/lead-in forming a small loop.
- Rx Lead-in drum needs to have the connectors horizontally as shown in Figure 10.
- Stay away from the Rx coil (stay outside the TX coil) when recording data.
- Do not place conductive materials (metal) close to the coils, especially the Rx coil.
- An accuracy of the Rx coil center position within 2 m is acceptable. The Rx coil area should match the nominal area within a few percentages.

Figure 10. Lead-in cable drum (left) with connectors for receiver cable. Yellow marking showing the meeting point between lead-in cable and Tx coil.

4.4 Operate sTEM controller app to collect data

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

1. sTEM type in settings (i.e. sTEM or sTEMprofiler).
2. Protocol (i.e. Protocol_Tx40x40_Rx3x3_20ms_50Hz.sts).
3. Measuring time.

4.5 De-mobilize the system

- Turn-off sTEM PC from the STEM Controller app and power off the sTEM unit with the power button on the sTEM unit.
- Disconnect cables and put on the protection caps on the plugs.

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.

5. STEMPROFILER – FIELD OPERATION GUIDE

A field crew of two people is recommended to operate the sTEM profiler efficiently.

The workflow for performing a series of sTEMprofiler measurements goes through the following steps:

1. Powering on the sTEM unit.
2. Assemble the frame and attach the Tx and Receiver coils.
3. Operating the sTEM 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 sTEM unit

To turn on the sTEM unit do:

- Insert two RRC 2054-2 batteries in the battery slots in the sTEM unit (see Figure 5).
- 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 5).

- 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 sTEM unit before rolling out the cables.
- 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 sTEMprofiler coils

Follow the 5 steps below to assemble the sTEMprofiler (Figure 11-Figure 15).

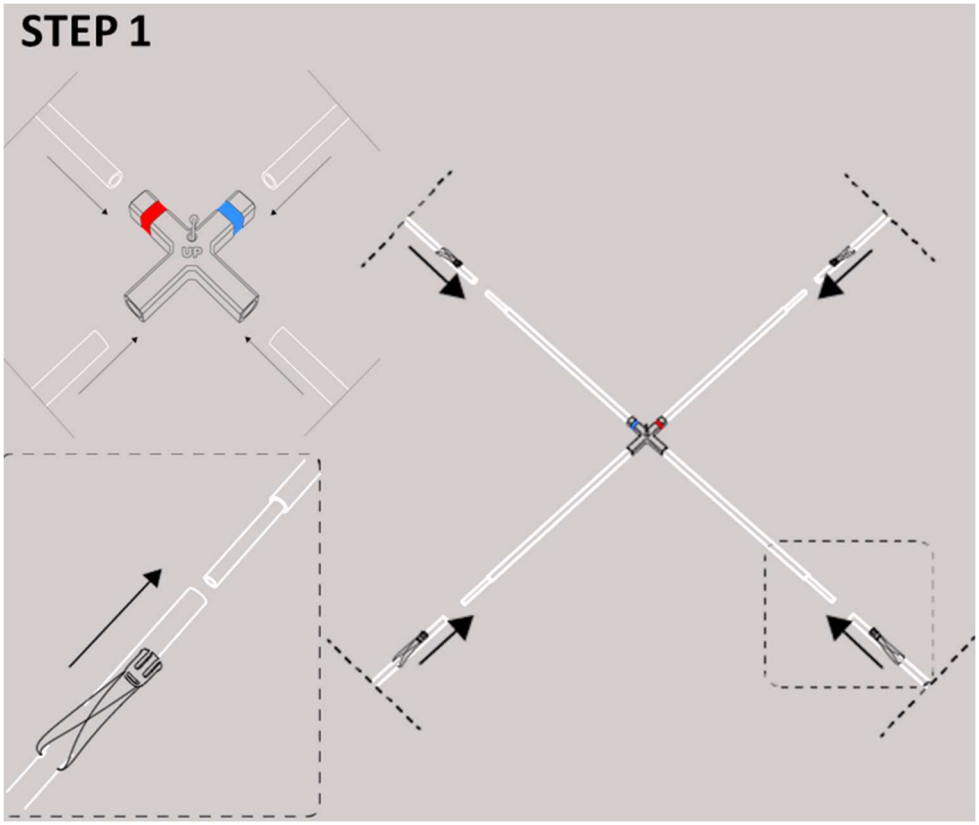

Figure 11. Assembling rods into center piece.

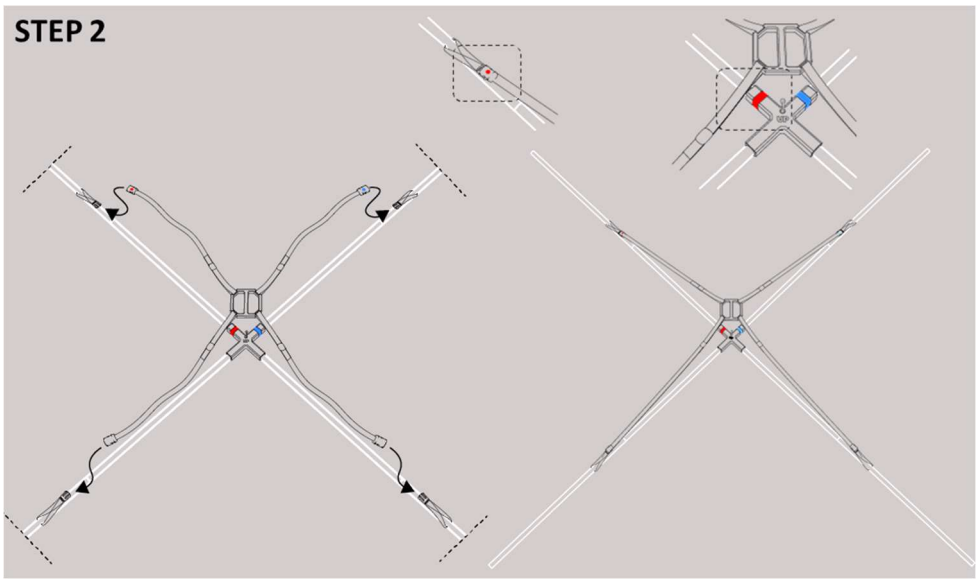

Figure 12. Clipping in the handles.

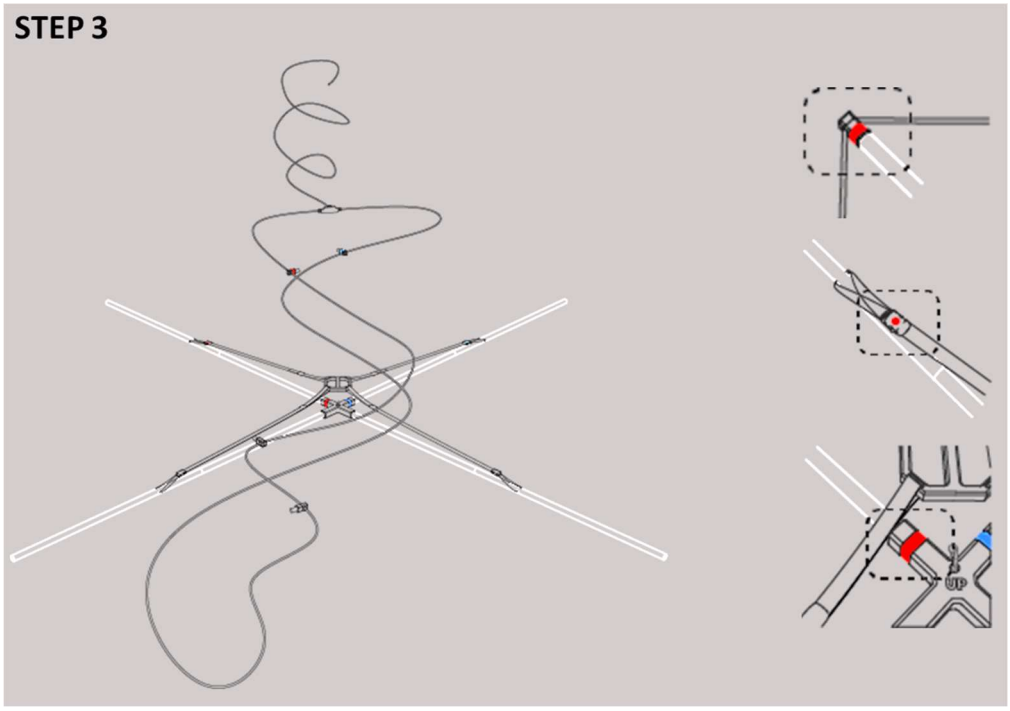

Figure 13. Mounting Rx and Tx coils.

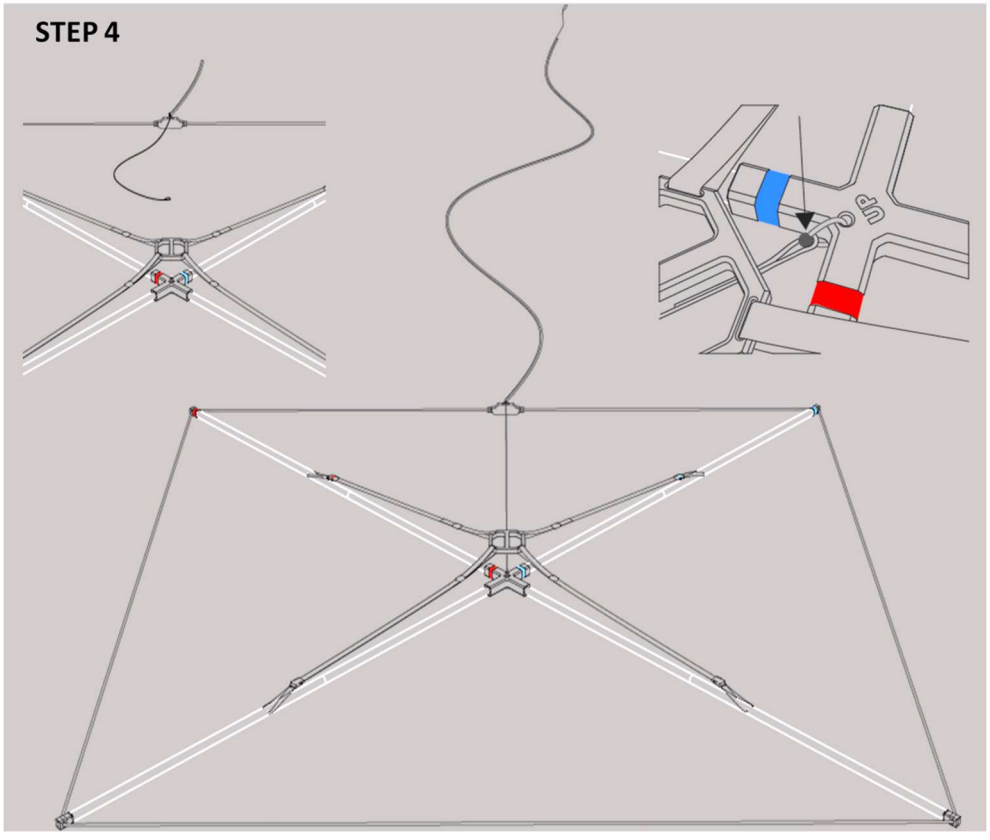

Figure 14. Clipping in towing safety ropes.

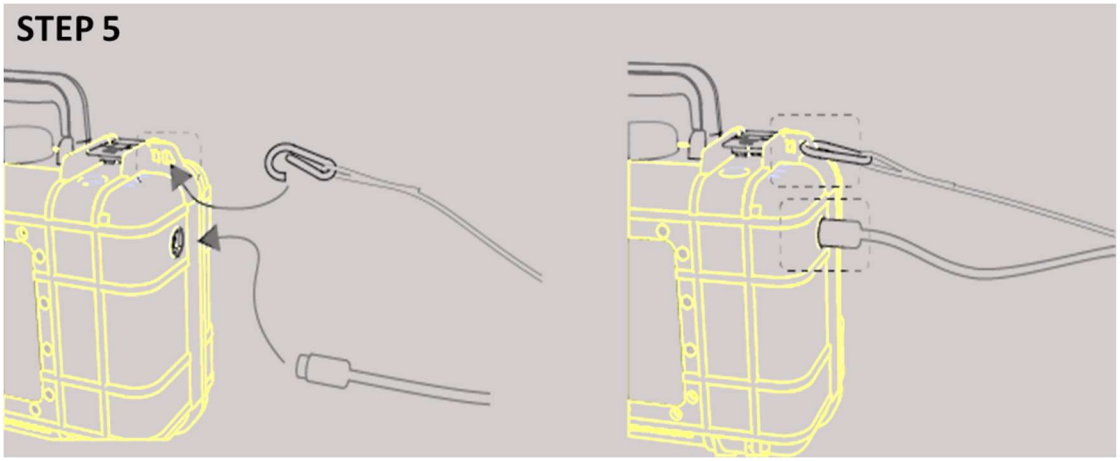

Figure 15. Connecting to sTEM instrument.

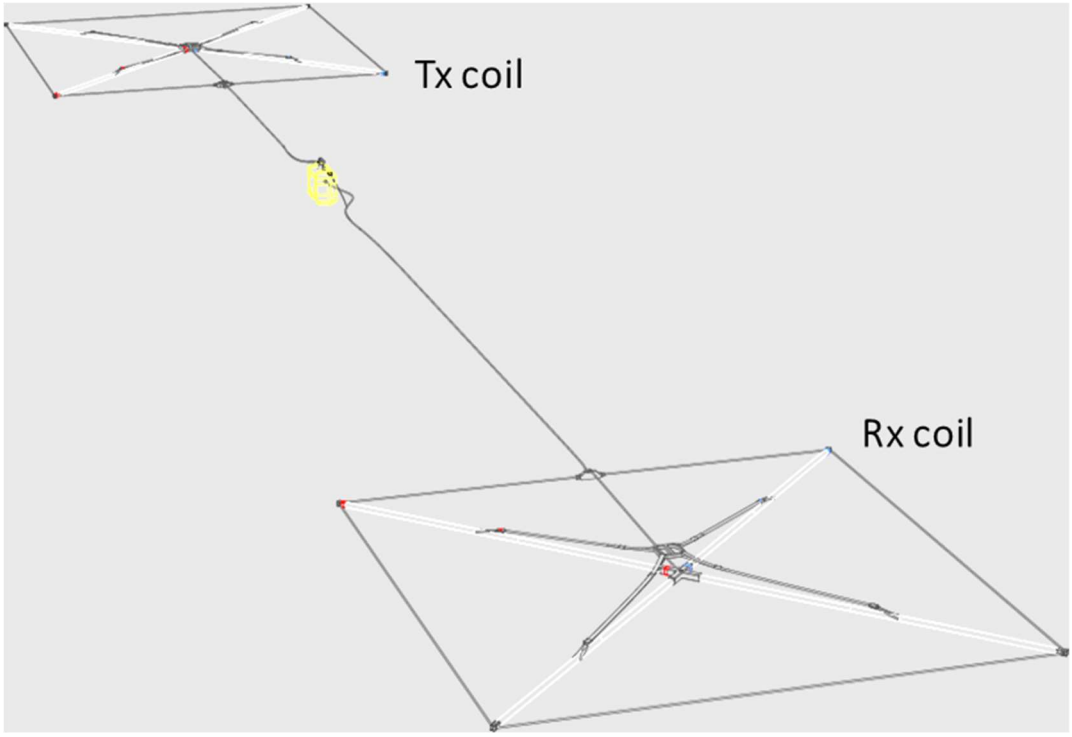

Figure 16. Fully assembled sTEMprofiler system.

5.3 Operate sTEM Controller app to collect data

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

4. sTEM type in settings (select sTEMprofiler)
5. Protocol (eg. Protocol_Tx3x3_Rx3x3_4600us_50Hz.sts)
6. Measuring time (eg. ½ or 1 minute)

Note:

- When sTEMprofiler 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 frames and sTEM unit and move to the next station. Place frames down and move out of the loops before measuring.

5.5 De-mobilize the system

- Turn-off sTEM PC from the STEM Controller app and power off the sTEM unit with the power button on the sTEM unit.
- Disassembly frames and put on the protection caps on the plugs.

6. STEM CONTROLLER APP

Installing the sTEM Controller App

The sTEM system is controlled by the sTEM Controller app available for both Android and iOS and can be installed from Google Play/App Store (search for “sTEM Controller”, see Figure 17).

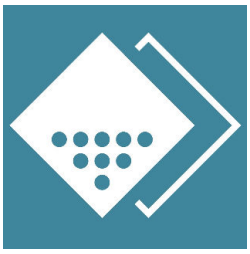

Figure 17. sTEM Controller app icon.

Connecting to the sTEM unit

- Make sure the sTEM unit is turned on. It needs to run for a few minutes to set up the sTEM Wi-Fi.
- From the mobile device **connect to sTEM** Wi-Fi network.
  Wi-Fi name: sTEM_0### (ID of the sTEM instrument).
  Password: 0102030405060708
- **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 sTEM unit.
- Open the sTEM Controller app, which should display the controller interface as shown in Figure 18, if proper connected.

sTEM Controller App - Introduction

Figure 18 explains the interface of the sTEM controller App.

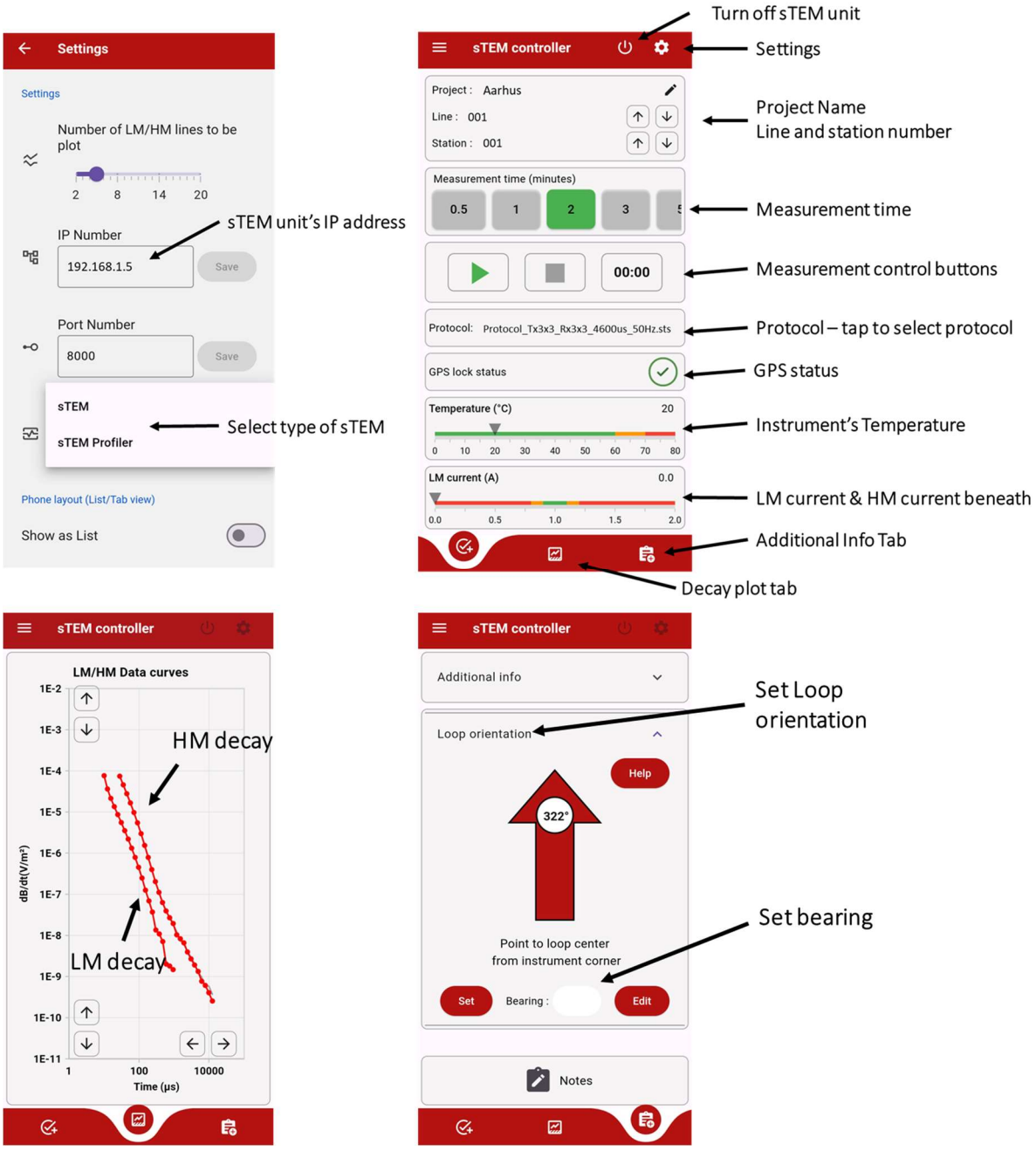

Figure 18. sTEM Controller app environment. Version 1.1.0.

Protocols

The protocol file defines the measurement sequence of the sTEM unit and contains key information for accurately modeling 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.

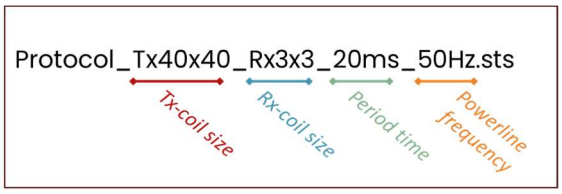

Figure 19. Protocol naming.

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 19Figure 19. 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 sTEM unit records the GPS position where the unit is placed. To correct the GPS-position to the center of the Rx coil, the bearing (geographical direction) from the sTEM unit to the Rx coil center is needed. When stopping a measurement, you will be prompted to set the bearing. using the build-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 Controller app to turn-off the sTEM PC, before powering off the sTEM unit.

Note

- If the connection between the sTEM unit and mobile device is broken, the measurement will continue until the *measurement time* is up. Re-connection to the sTEM is possible.
- Several mobile devices can be connected to the sTEM 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 sTEM 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 sTEM 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.

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 TEM-company or reseller Minor damage on Tx coil 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 coil 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 sTEM unit from a cold outdoor to a warm inside: Do not power on the sTEM 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 sTEM will automatically stop if the internal temperature exceeds 75 °C. The internal temperature can be monitored in the Controller app.

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

Personal safety

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

8. DOWNLOAD DATA FROM STEM UNIT

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

Connecting to sTEM Wi-Fi

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

- Insert both batteries in the sTEM unit and turn it on.
- From the *Local PC* connect to sTEM Wi-Fi network. (see Figure 20, top)
  Wi-Fi name: sTEM_0###,
  Password: 0102030405060708

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.

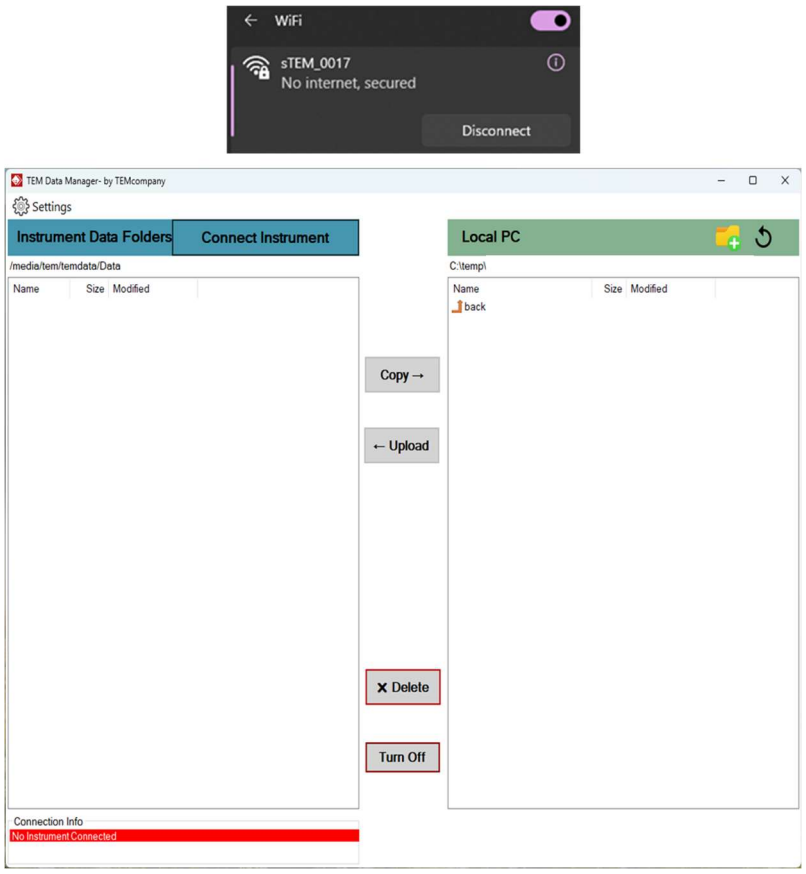

Figure 20. Top) Example of sTEM unit's Wifi network name. Bottom) Main window of TEM data Manager program (when not connected to the instrument).

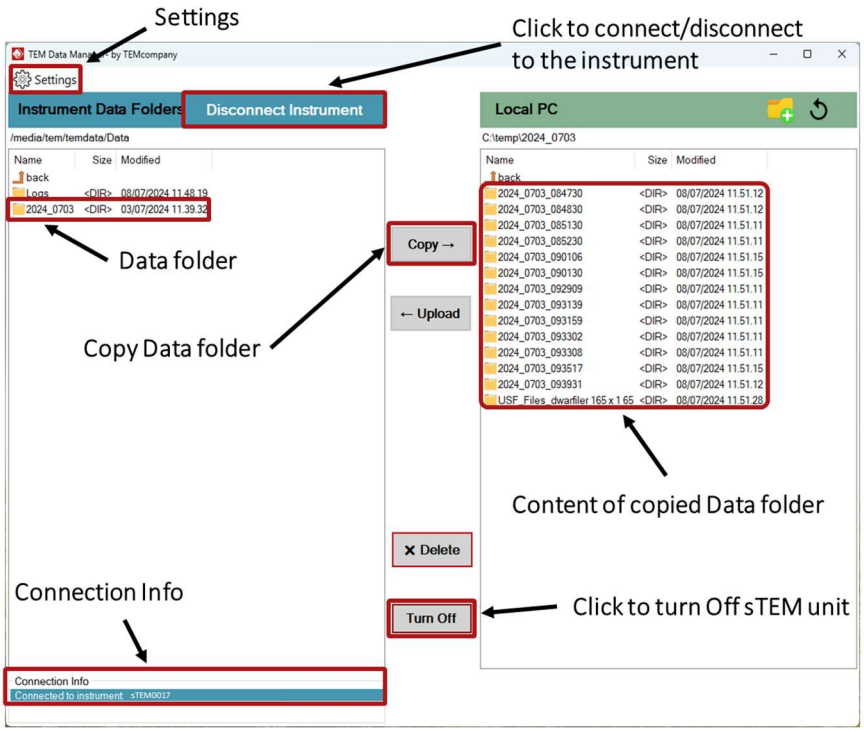

Figure 21. Steps for copying data from sTEM unit (after connecting to the instrument).

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 sTEM 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 data-time name (yyyy_mmdd_hhmmss) and should contain one stb-file and one stn-file (Figure 21).
- 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 of the Instrument PC from the sTEM Controller app before turning off the sTEM unit.

Note

- Folders/files with date/time names are named using UCT-time (GPS date/time).
- User notes from the sTEM controller 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 sTEM unit.

9. TROUBLESHOOTING – FAQ

STEM Controller app

Symptom/problem	Solution
The sTEM Wi-Fi does not show up on mobile device	Note that it takes a few minutes from turning on the sTEM unit until sTEM Wi-Fi is available. Check sTEM 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 sTEM unit. Re-start the sTEM unit via the power button.
sTEM controller/sTEM Wi-Fi keep disconnecting	Make sure that the mobile data connection is turned off on the mobile device. Move closer to the sTEM 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 sTEM 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 sTEM 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 coil connection to the sTEM unit (clean plugs if needed). Check batteries stage of change / replace batteries. Tx-80x80 m coil: Check Tx coil corner connections as well.
"Alternating sign pattern not detected" error	With the Rx coil placed inside the Tx coil It is fundamental that the primary field from the Tx coil, 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 up.
The TEM signal looks very noisy	Check connections between receiver coil and lead-in cable and/or lead-in and sTEM 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)	sTEM 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 TEMcompany 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 sTEM remotely

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

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

First a PC must connect to the sTEM's Wi-Fi. Wifi password is: 0102030405060708

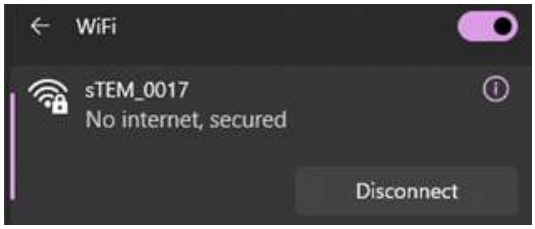

Figure 24. Example of sTEM unit's Wifi name on Wifi networks.

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

Figure 25. Remote Desktop Connection to sTEM 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 sTEM 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 sTEM unit accessible remotely by opening the TeamViewer program. The ID and password must be informed to the TEMcompany employee.

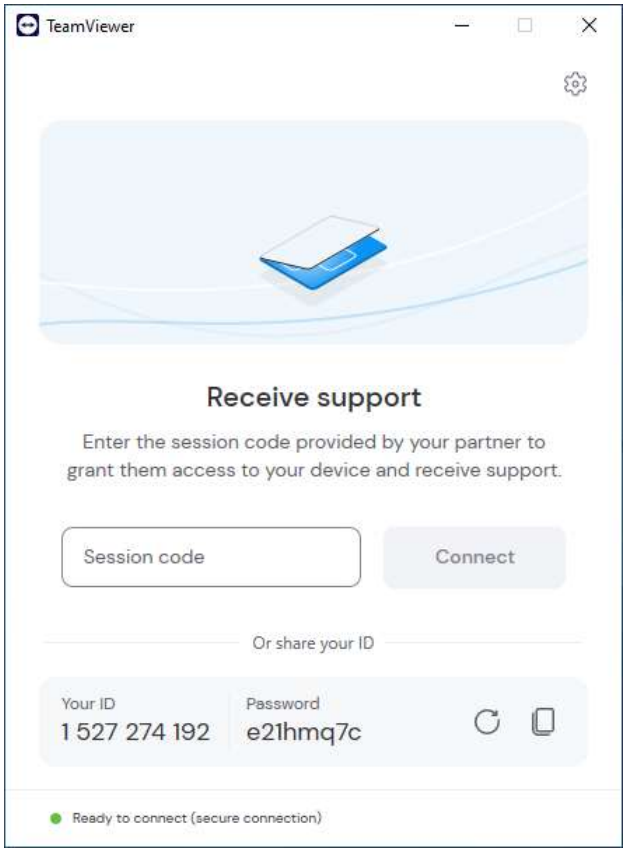

Figure 26. Example of what the TeamViewer ID and password should look like.

APPENDIX I: HOW TO HANDLE STEM 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 Con-straint 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) .

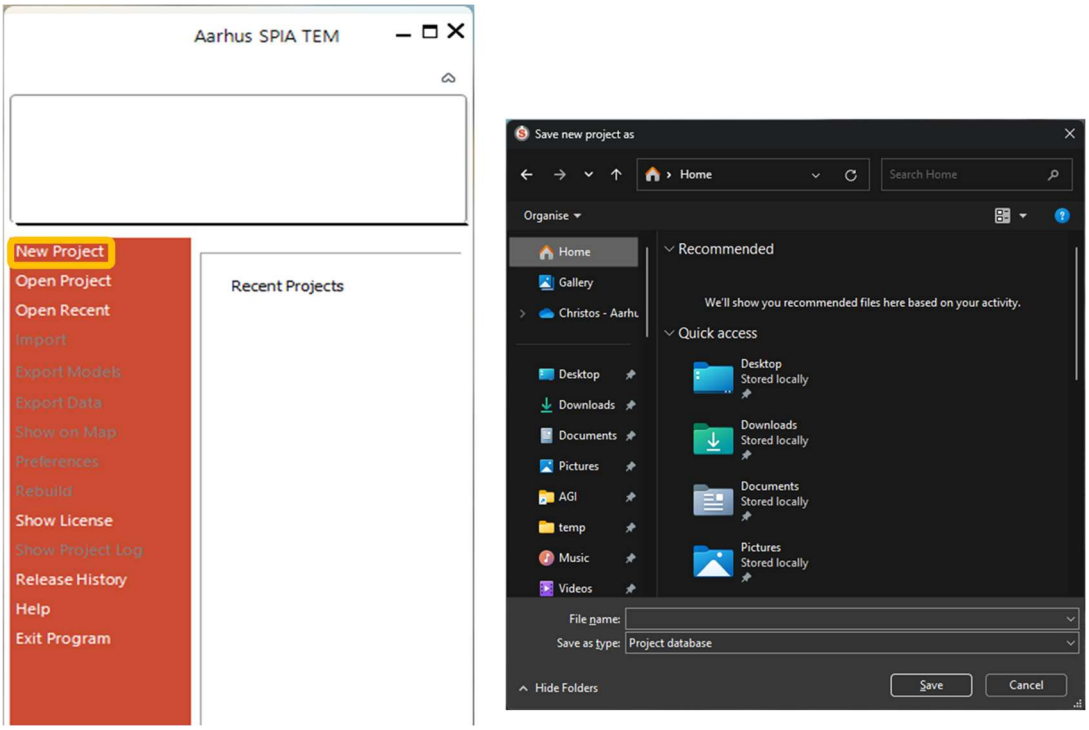

Figure 27. Steps to make a new project in SPIA software.

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

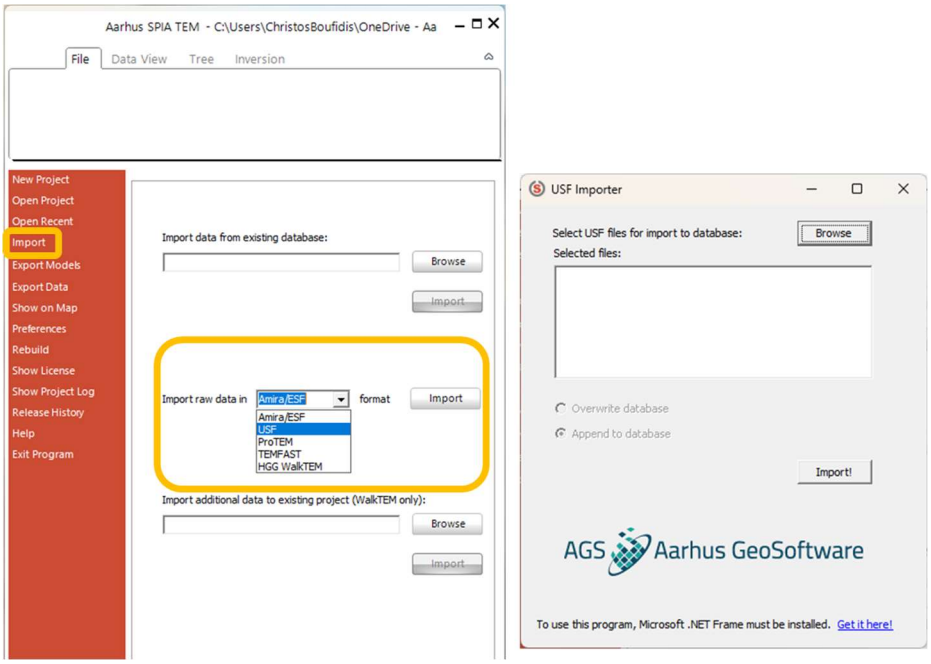

Figure 28. Data import. Select USF format and browse to locate the .usf files.

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

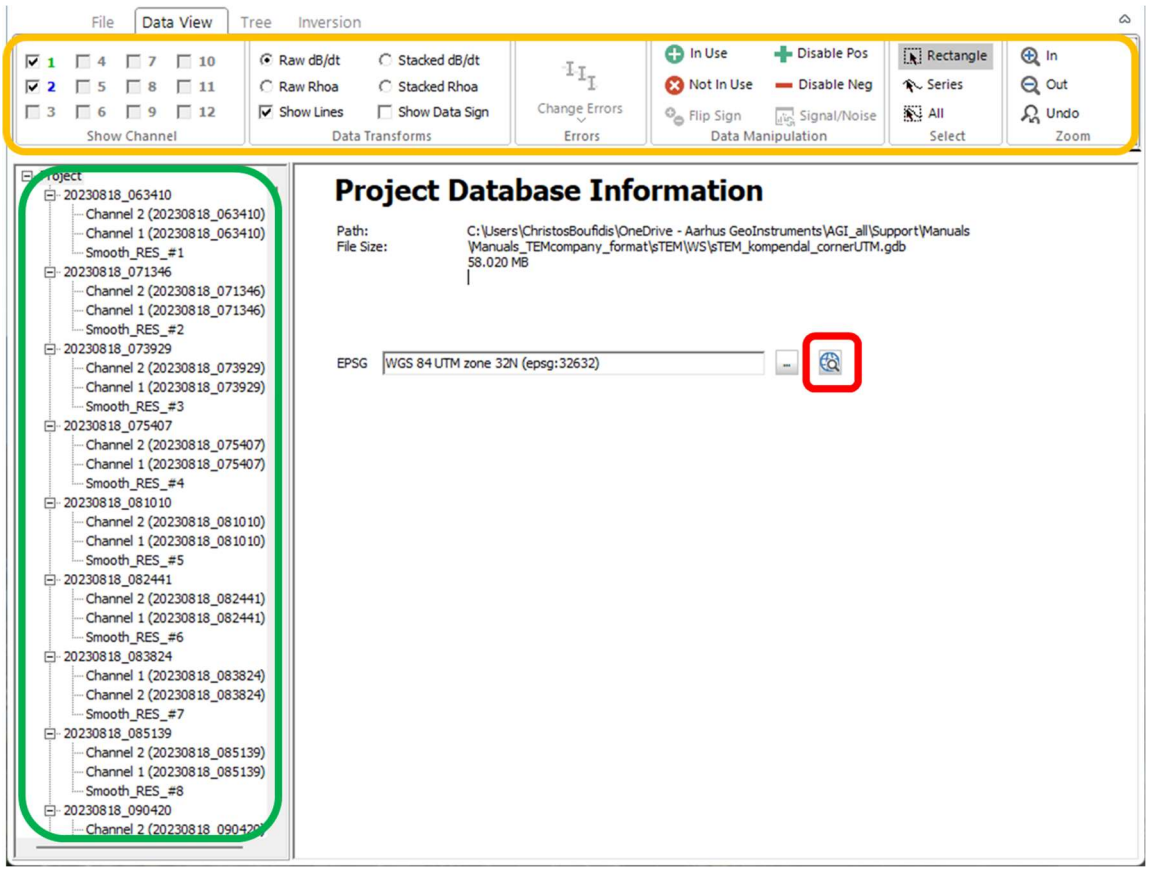

Figure 29. SPIA interface. On the left is the data tree (green) with the stations named based on the date and time of measurement. In yellow is the Data view ribbon with options and tools for data processing.

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

sTEM 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. Doing the latter one helps to do more detailed and precise processing.

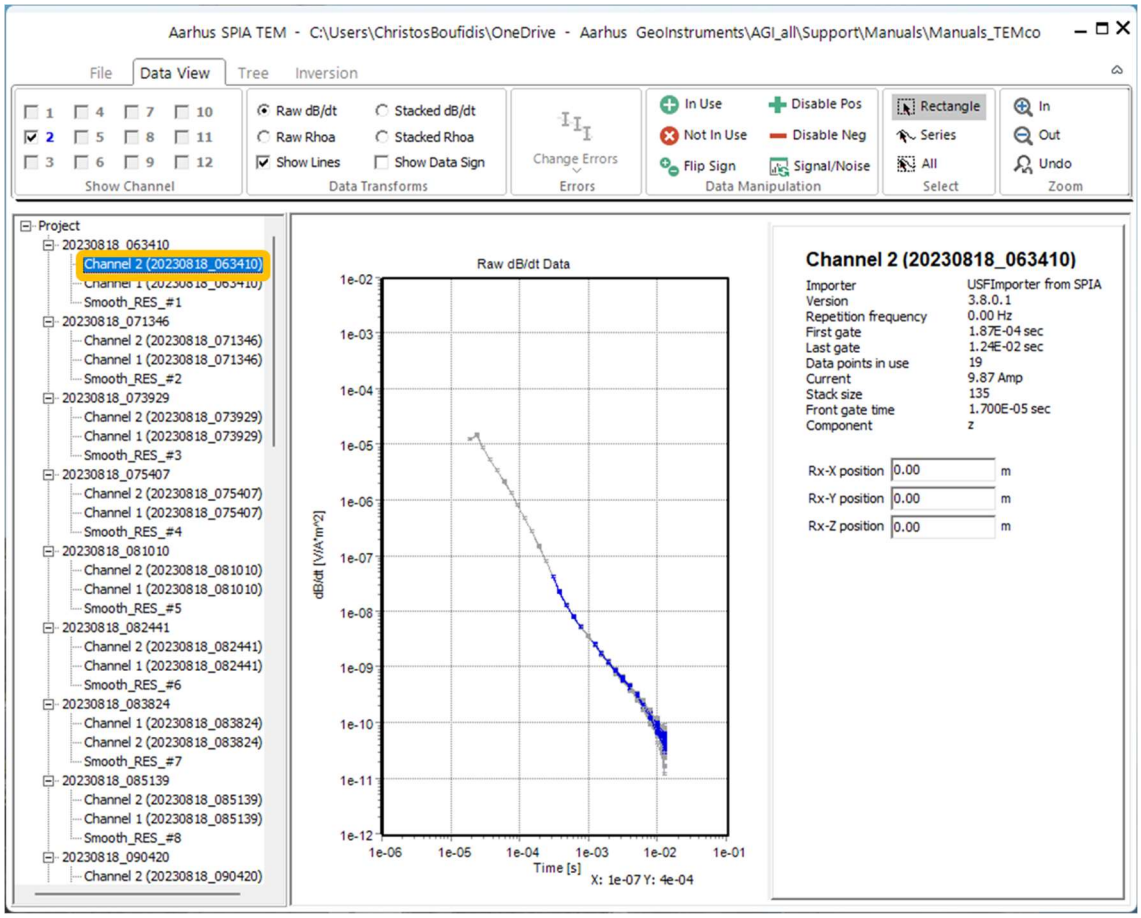

Figure 30. Processing window of SPIA. Select sounding to see both channels at once.

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").

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.

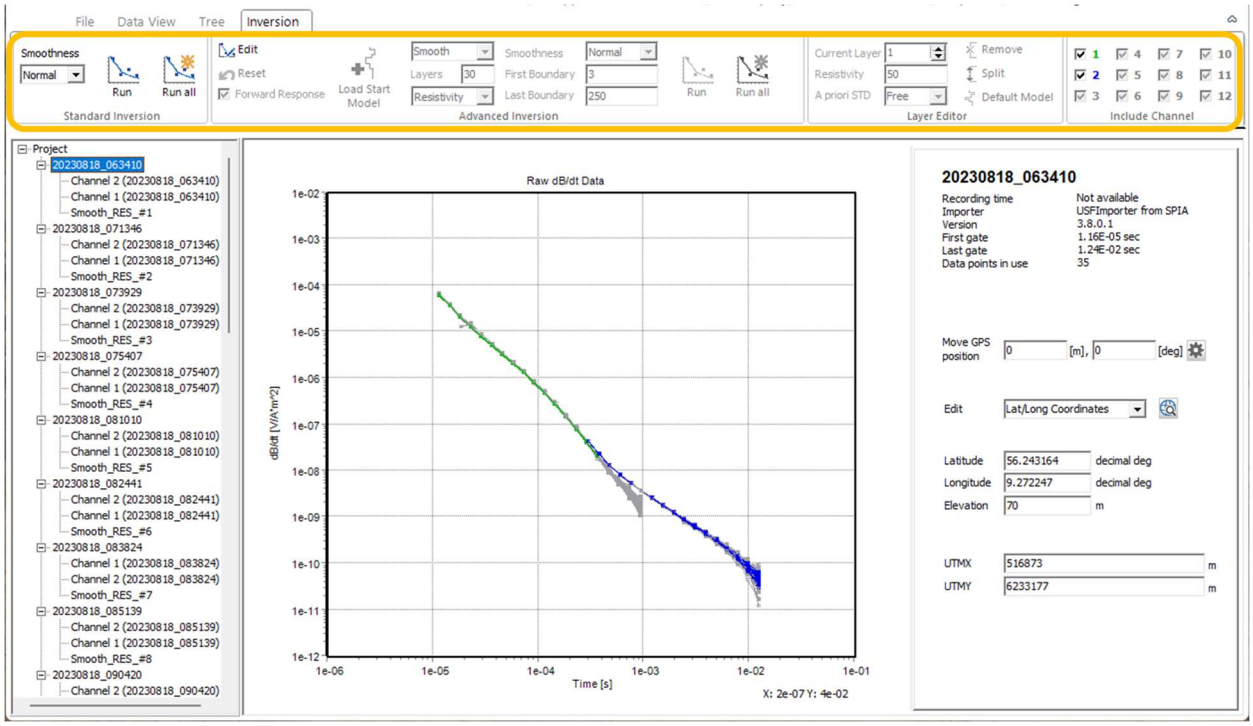

Figure 31. Inversion ribbon. Default options for inversion is presented on the left of the ribbon in "Standard Inversion" tab.

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 32 and Figure 33).

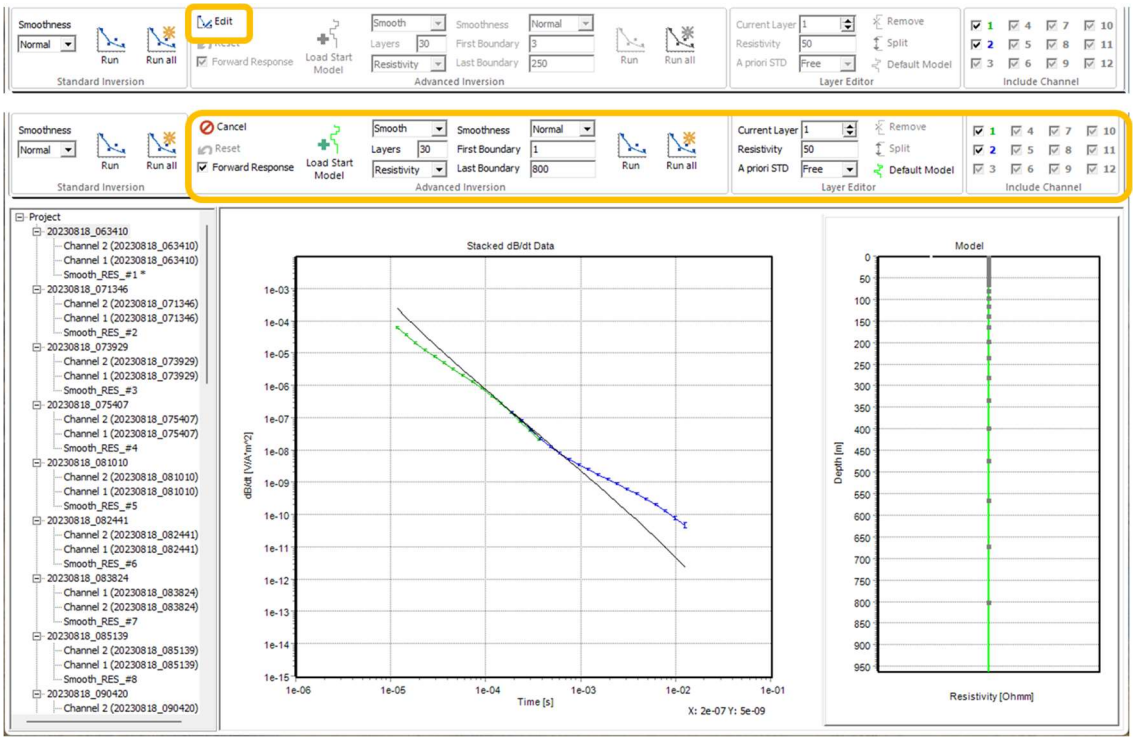

Figure 32. Manually edited inversion. Click on the "Edit" option available in the "Advanced Inversion" tab, and the different options for advanced inversion becomes available.

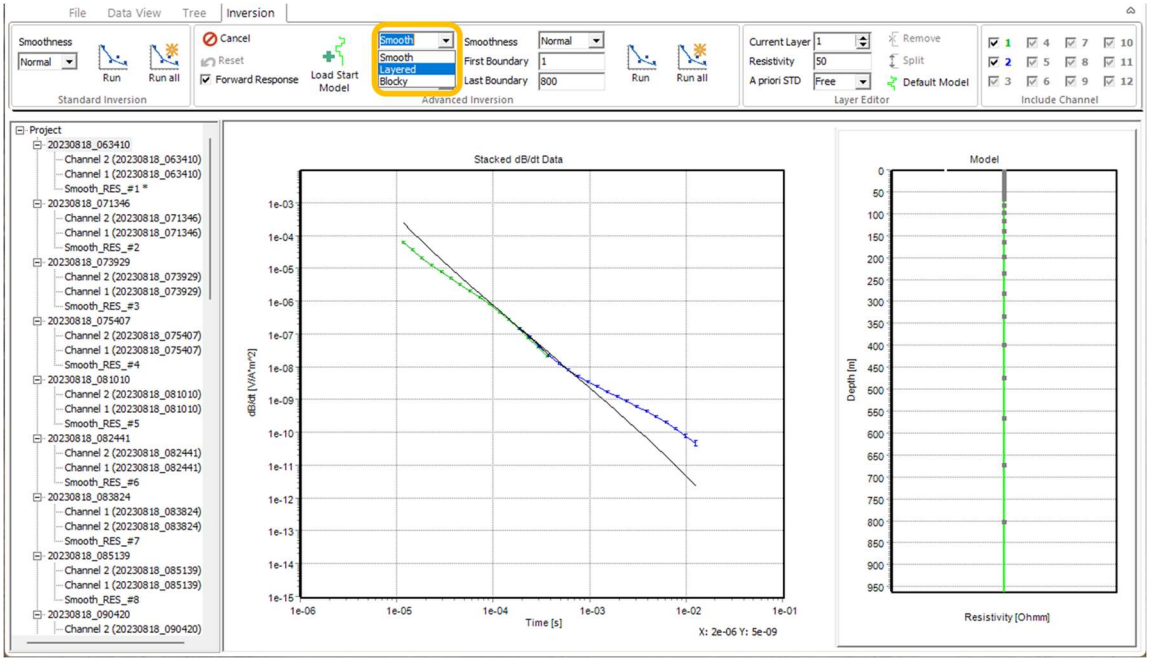

Figure 33. Inversion options for advanced inversion, such as Smooth, Layered and Blocky.

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**" tab. 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).

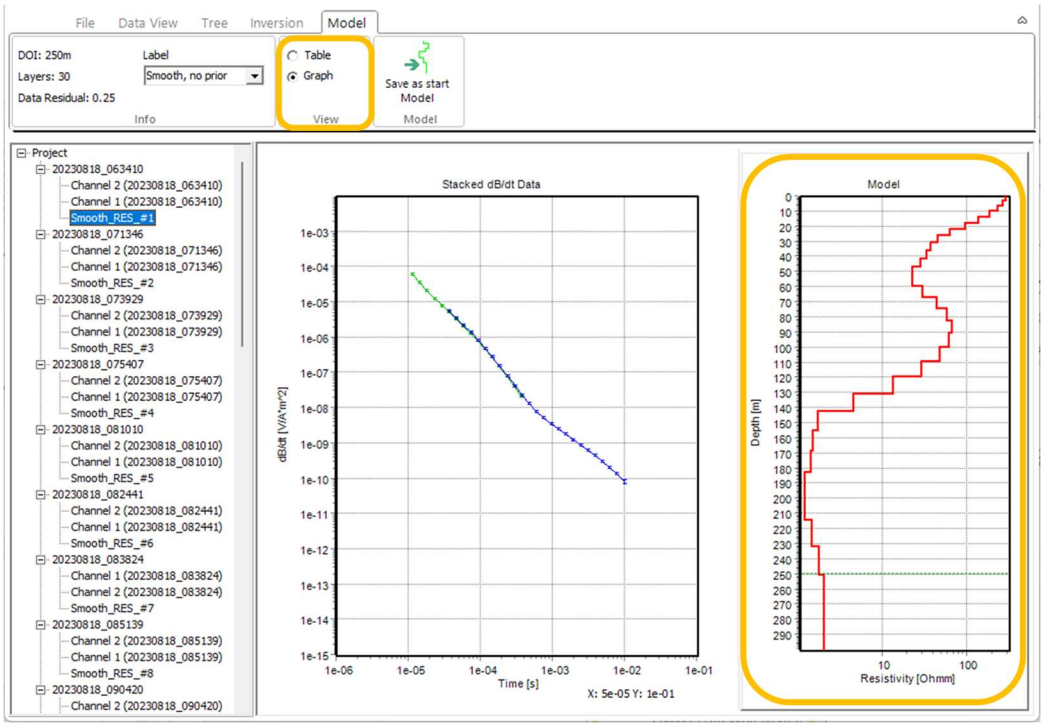

Figure 34. Inversion results display interface. Results are shown either as a graph (like the example above) or as a table.

2. IMPORT STEM SPIA MODELS IN WORKBENCH

Before importing sTEM 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.

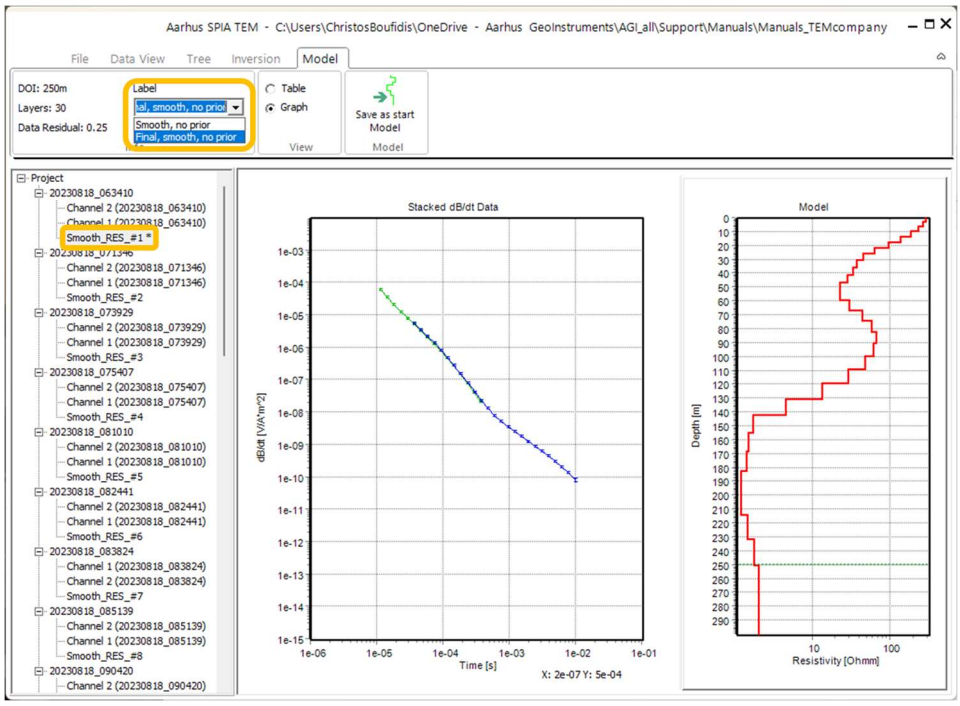

Figure 35. Export models by marking them with the label "Final" in model ribbon.

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.

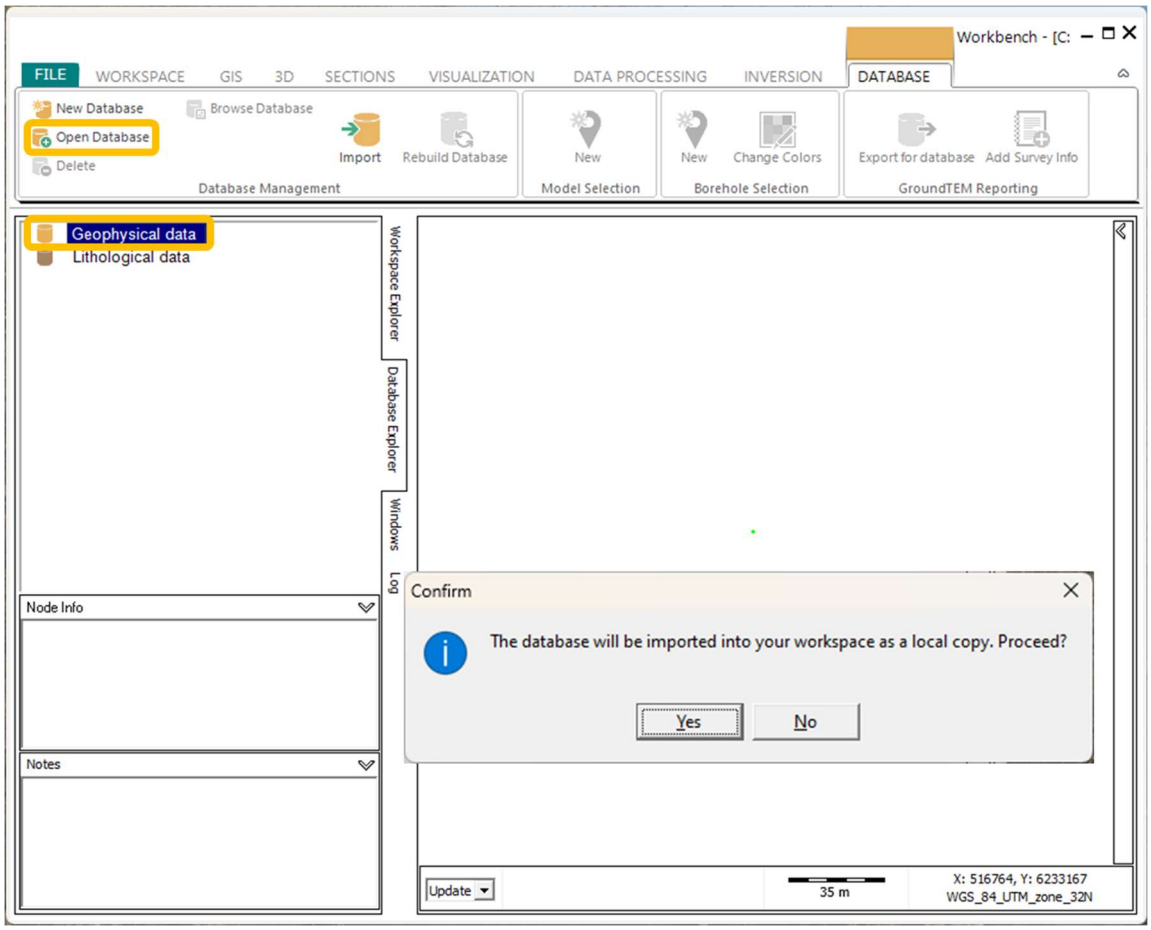

Figure 36. Import .gdb database from SPIA into Workbench. A confirmation window will pop up to complete the import in Workbench.

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).

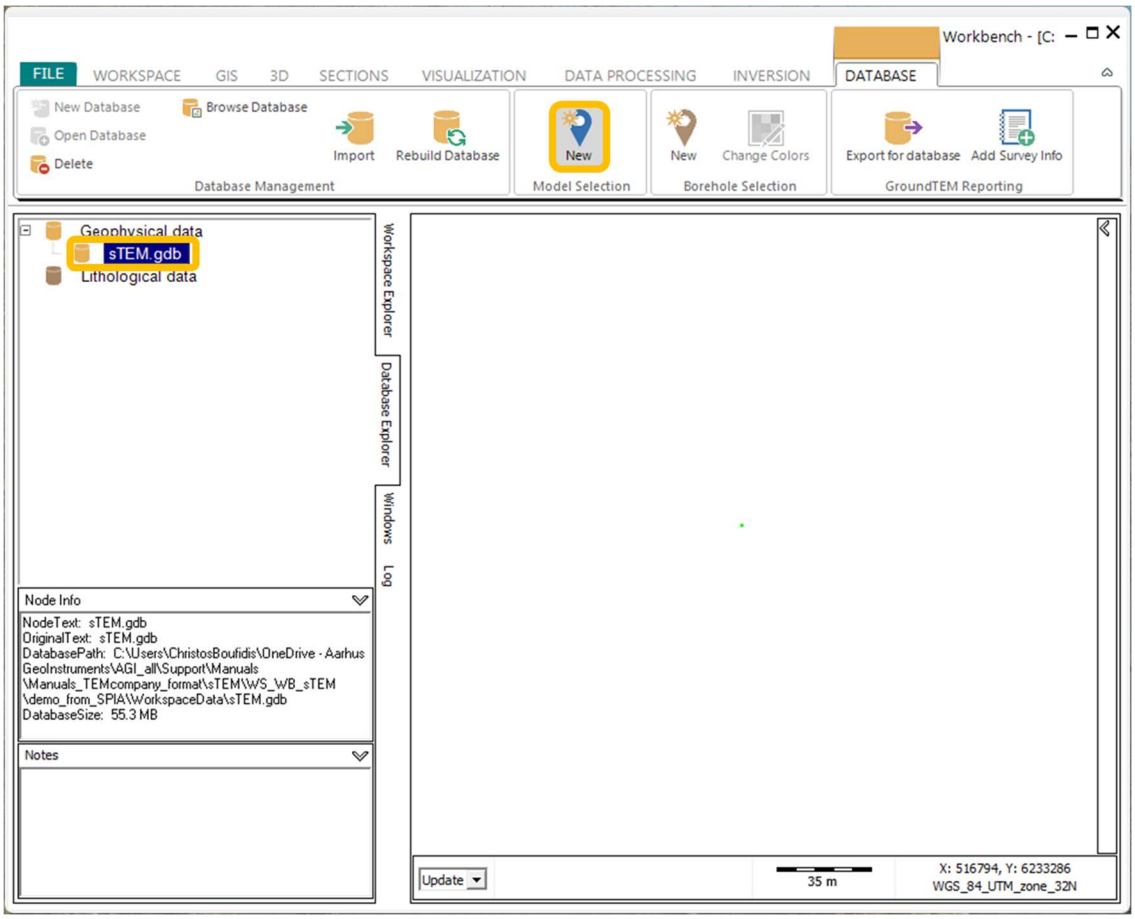

Figure 37. Create a "New" model selection after importing the sTEM database from SPIA.

Select the preferred database (Figure 38) and in "**New Model Selection**" choose the "**Select edition**" option. 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 labeling them with the "**Final**" label. Give a name to the model selection and click "**Ok**" to complete the process of importing.

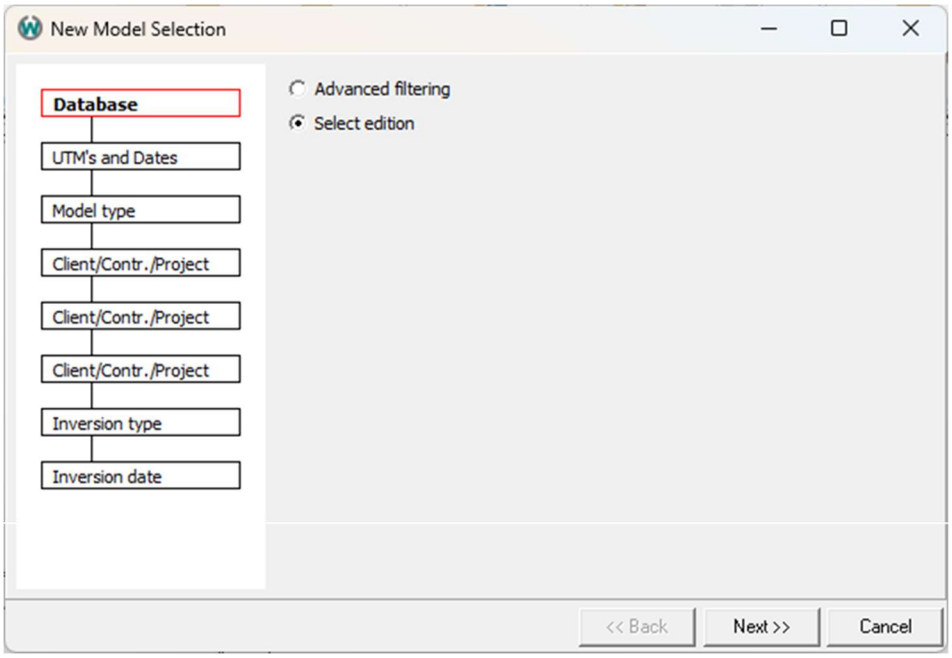

Figure 38. New model selection window where “Select edition” must be selected.

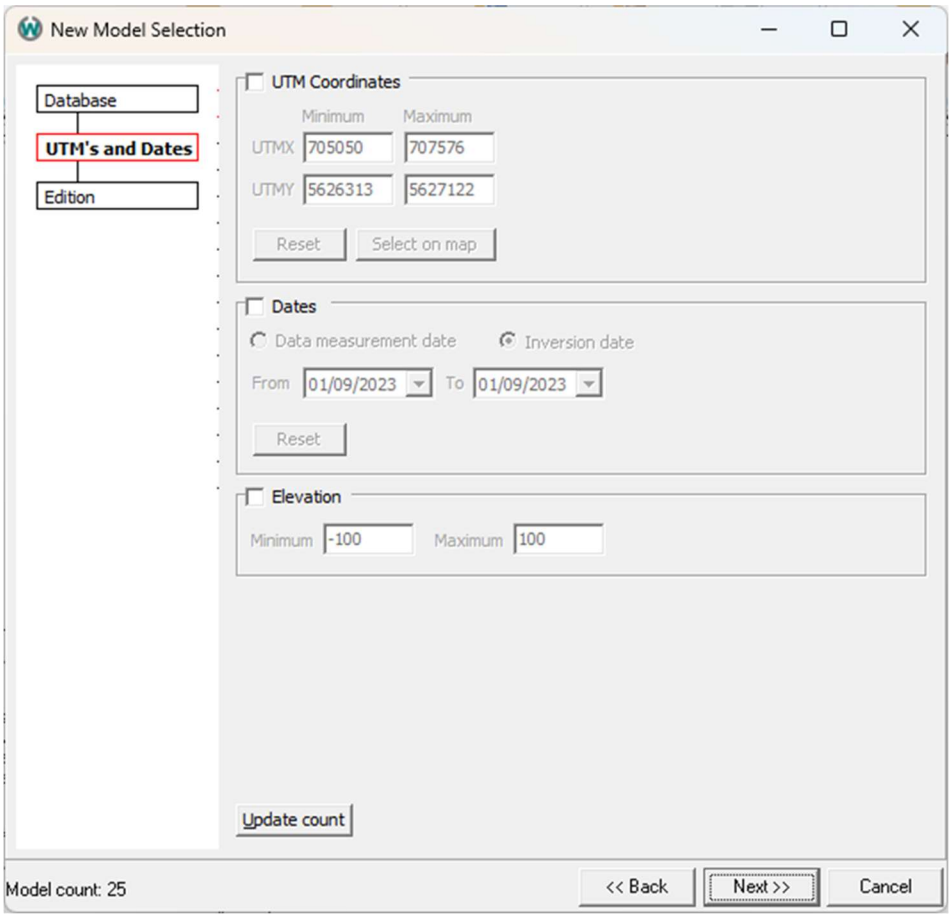

Figure 39. Specify UTM coordinates, Date or Elevation. Alternatively, select “Next” to proceed with the model selection.

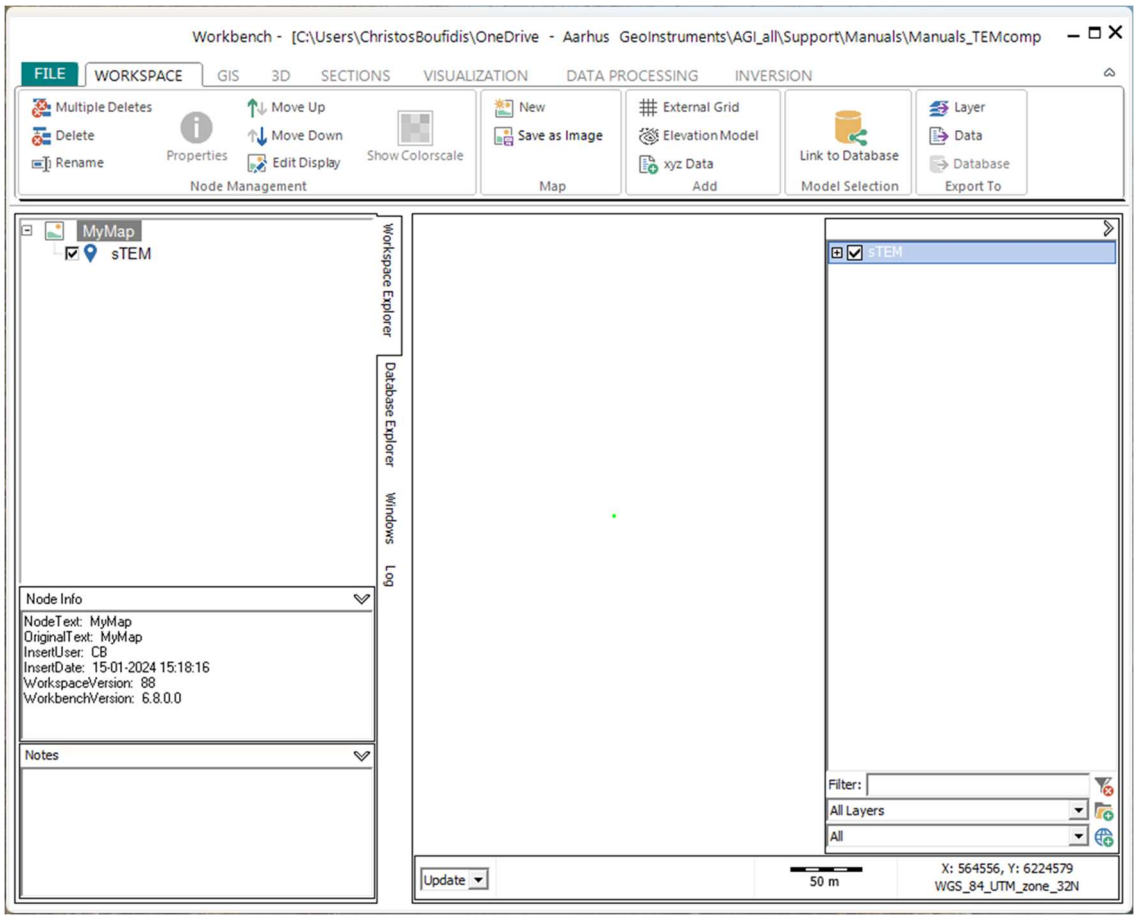

Figure 40. Model selection appears in Workspace explorer, on the left, as well as in the right in the GIS window.

2.1 LCI inversion of sTEM data in Workbench

sTEM 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.

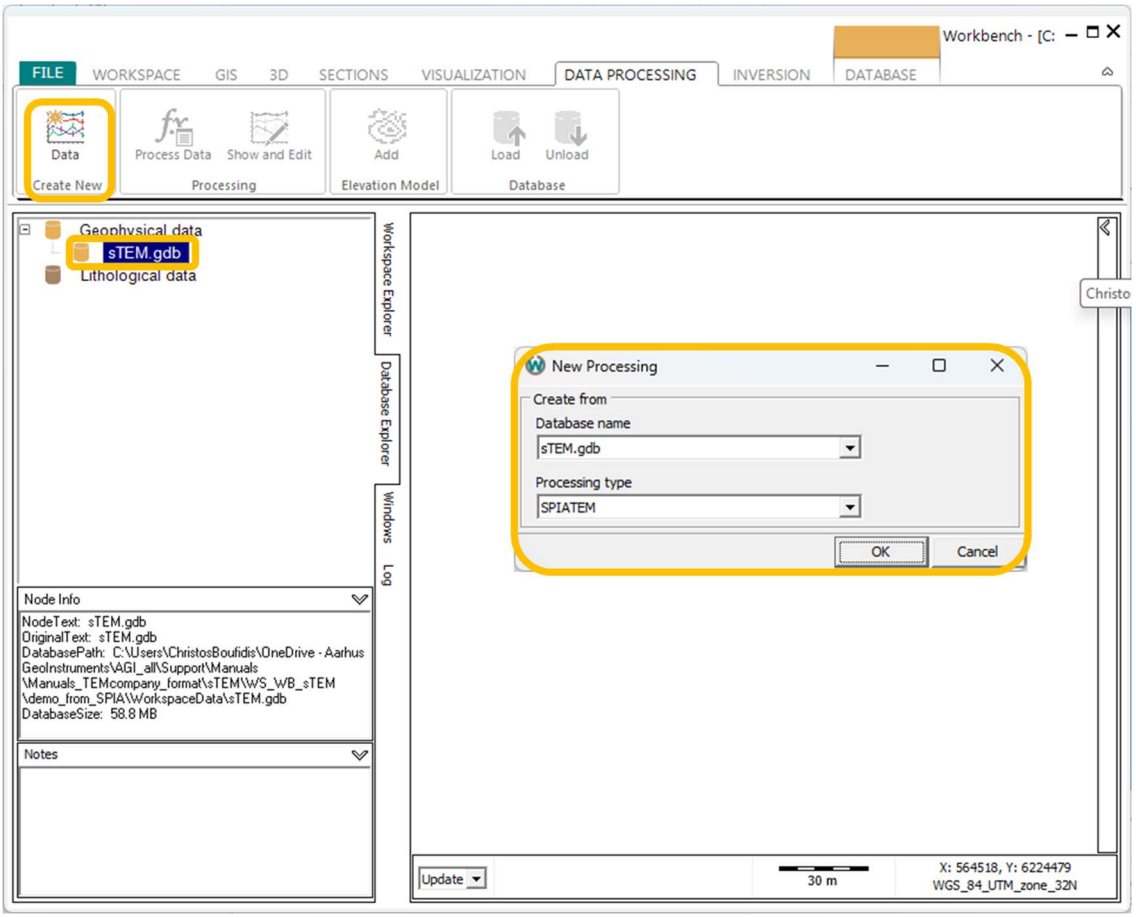

Figure 41. Steps for how to make a new processing node for sTEM data before the LCI inversion.

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).

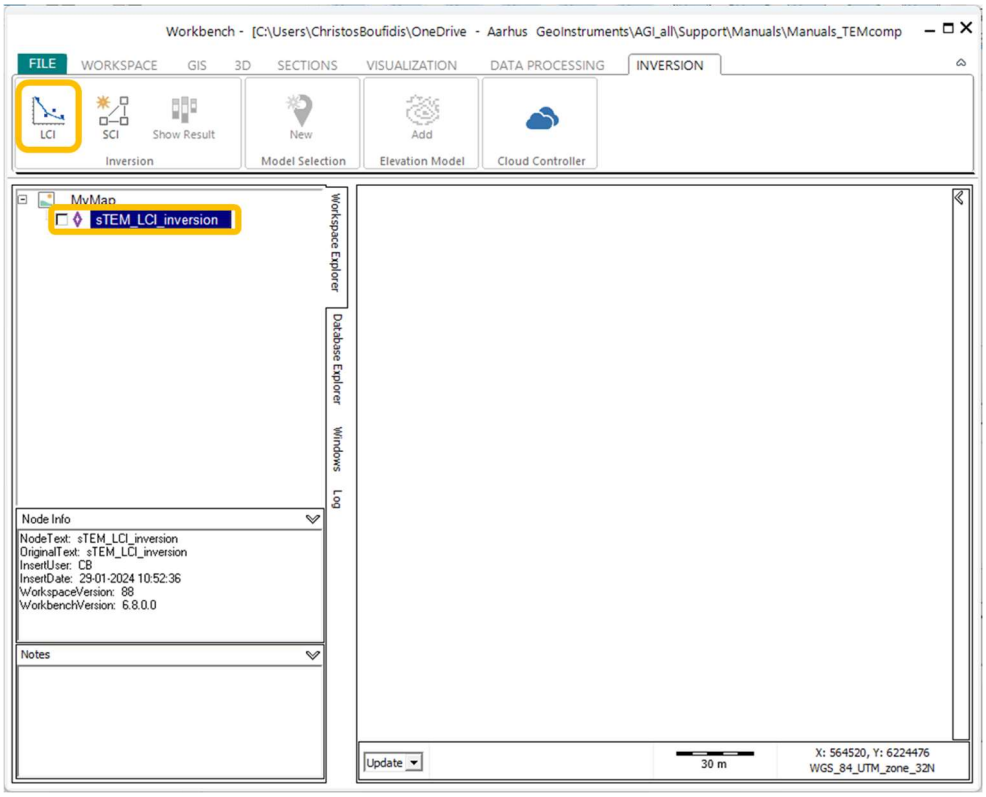

Figure 42. sTEM data processing and the LCI inversion has been selected.

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.