ERTLAB STUDIO

TUTORIAL # 2
ERT Data processing

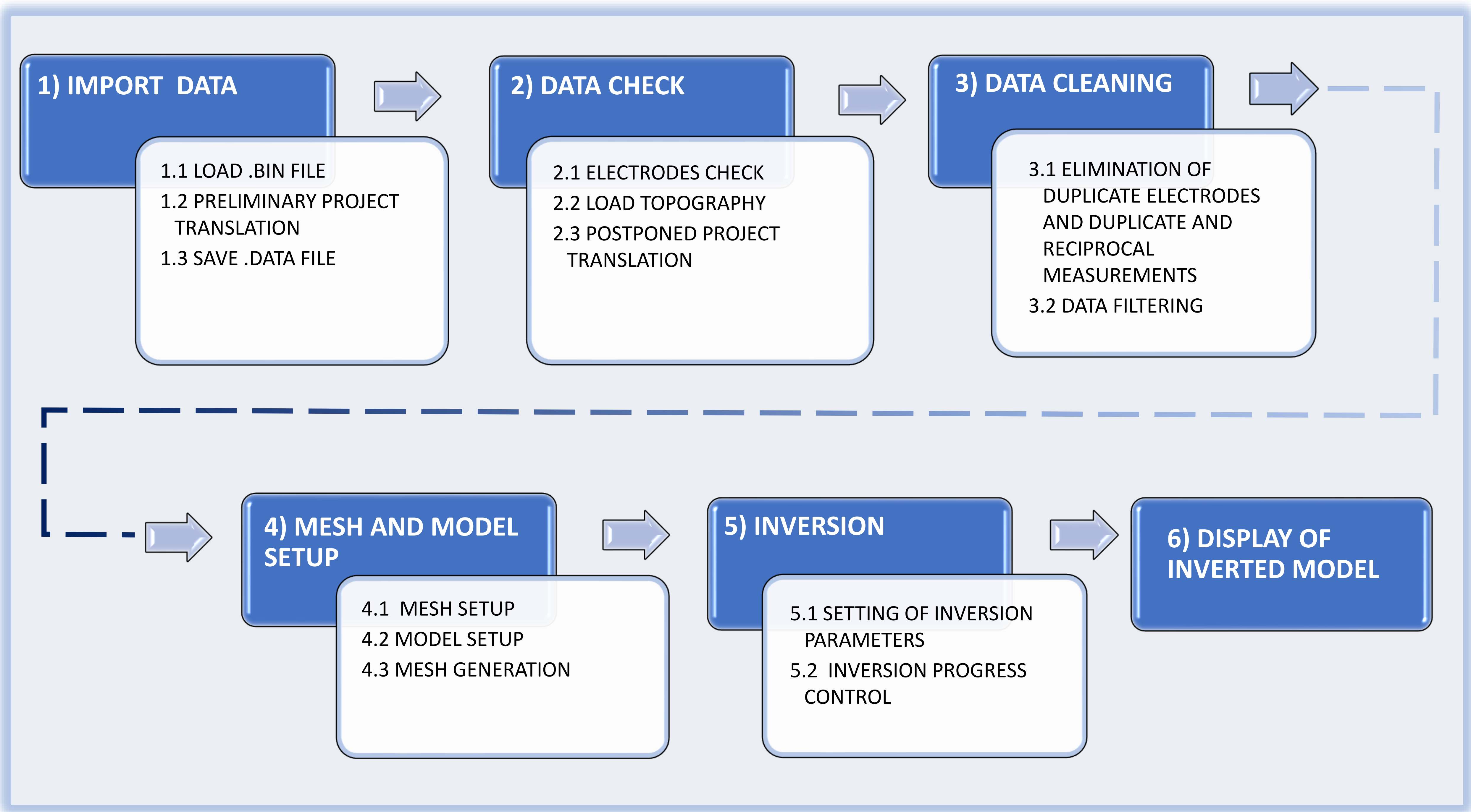
www.geostudiastier.com

v.1.0

GEOstudi Astier

ERTLab *Studio*

WORKFLOW CHART FOR ERT DATA PROCESSING



ERTLab *Studio*

WORKFLOW CHART FOR ERT DATA PROCESSING

1) IMPORT DATA

- 1.1 LOAD .BIN FILE
- 1.2 PRELIMINARY PROJECT TRANSLATION
- 1.3 SAVE .DATA FILE

2) DATA CHECK

- 2.1 ELECTRODES CHECK
- 2.2 LOAD TOPOGRAPHY
- 2.3 POSTPONED PROJECT TRANSLATION

3) DATA CLEANING

- 3.1 ELIMINATION OF DUPLICATE ELECTRODES AND DUPLICATE AND RECIPROCAL MEASUREMENTS
- 3.2 DATA FILTERING

4) MESH AND MODEL SETUP

- 4.1 MESH SETUP
- 4.2 MODEL SETUP
- 4.3 MESH GENERATION

5) INVERSION

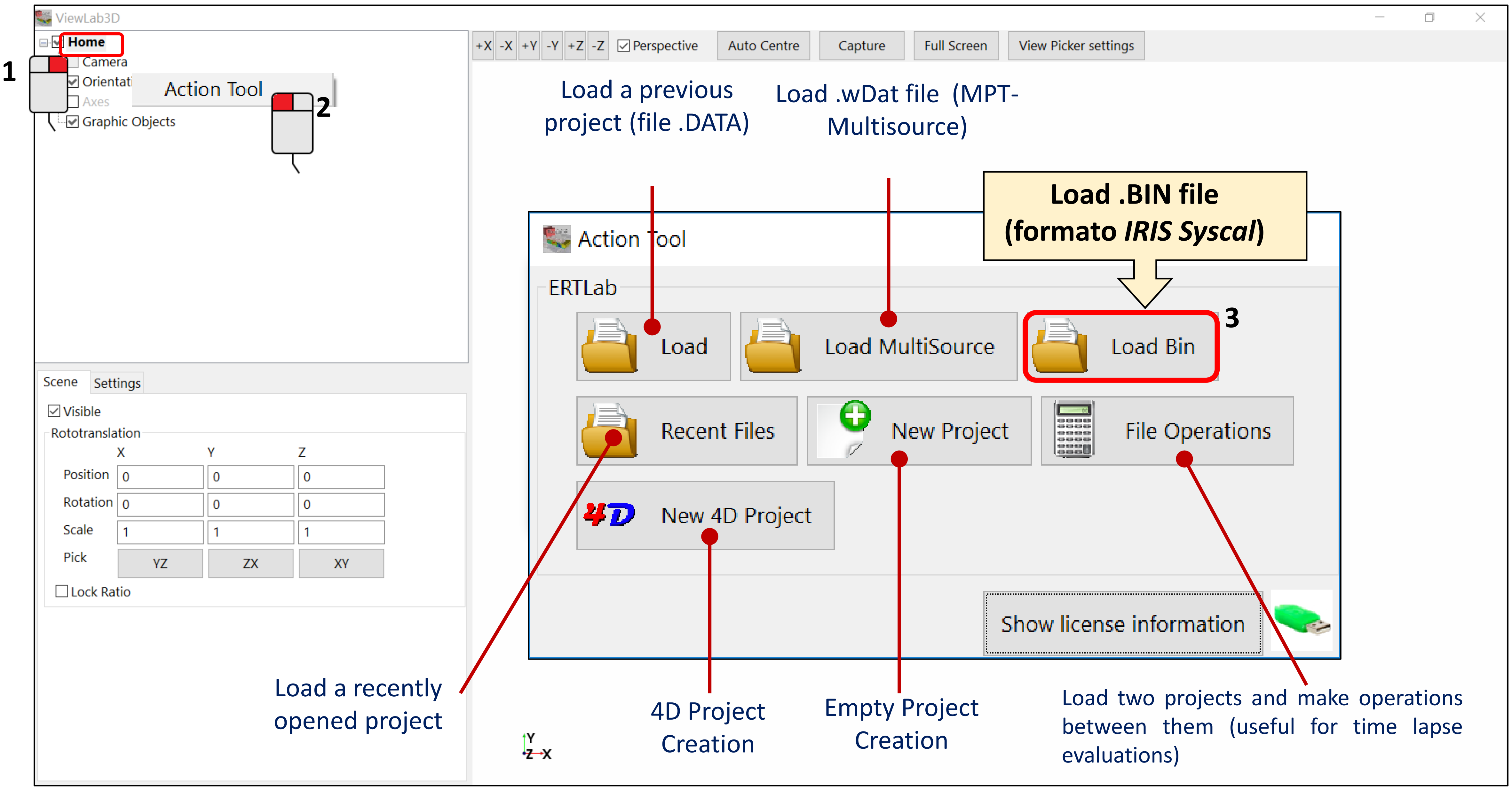
- 5.1 SETTING OF INVERSION PARAMETERS
- 5.2 INVERSION PROGRESS CONTROL

6) DISPLAY OF INVERTED MODEL

STEP 1: IMPORT DATA

1.1 Load .BIN file

This tutorial shows the basic steps for processing a single 2D line. *ERTLab Studio*, however, also optimally manage multi-line 3D acquisitions and unconventional electrodic configurations (for example, loop configuration). The process shown in this guide is valid even in these more complex cases.



STEP 1: IMPORT DATA

1.1 Load .BIN file

Each Syscal .BIN file can be associated to a **CONVERSION TABLE** to assign the electrodes to the coordinates (absolute or relative) to which the measurements are associated. Without the conversion table, data will be loaded with the coordinates used for the sequence acquisition.
The conversion table is a 7-column .txt file:

ELECTRODE NUMBER	SEQUENCE COORDINATES			REAL COORDINATES (absolute or relative)		
1	0	0	0	245.630	47263.770	86.000
2	2	0	0	245.950	47262.830	85.790
3	4	0	0	246.010	47261.910	85.610
4	6	0	0	246.010	47261.000	85.560
5	8	0	0	246.080	47259.940	85.590
6	10	0	0	246.280	47258.900	85.770
7	12	0	0	246.460	47257.990	85.690
8	14	0	0	246.540	47257.280	85.150
9	16	0	0	246.620	47256.090	84.410
10	18	0	0	246.900	47255.240	84.280
11	20	0	0	246.950	47254.310	84.050
12	22	0	0	247.120	47253.540	84.060
13	24	0	0	247.200	47252.370	83.790

ERTLab *Studio* automatically reads the conversion table when the .BIN file is load, provided that the two files have the SAME NAME:

Example

File .BIN → **Example Line .BIN**
Associated Conversion Table → **Example Line.TXT**

In case of acquisition with REMOTE POLE it is possible to:

- When project is loaded, check ✔ in REM coloumn of the coorresponding electrode (in electrodes table, Paragraph 2.1)

OR

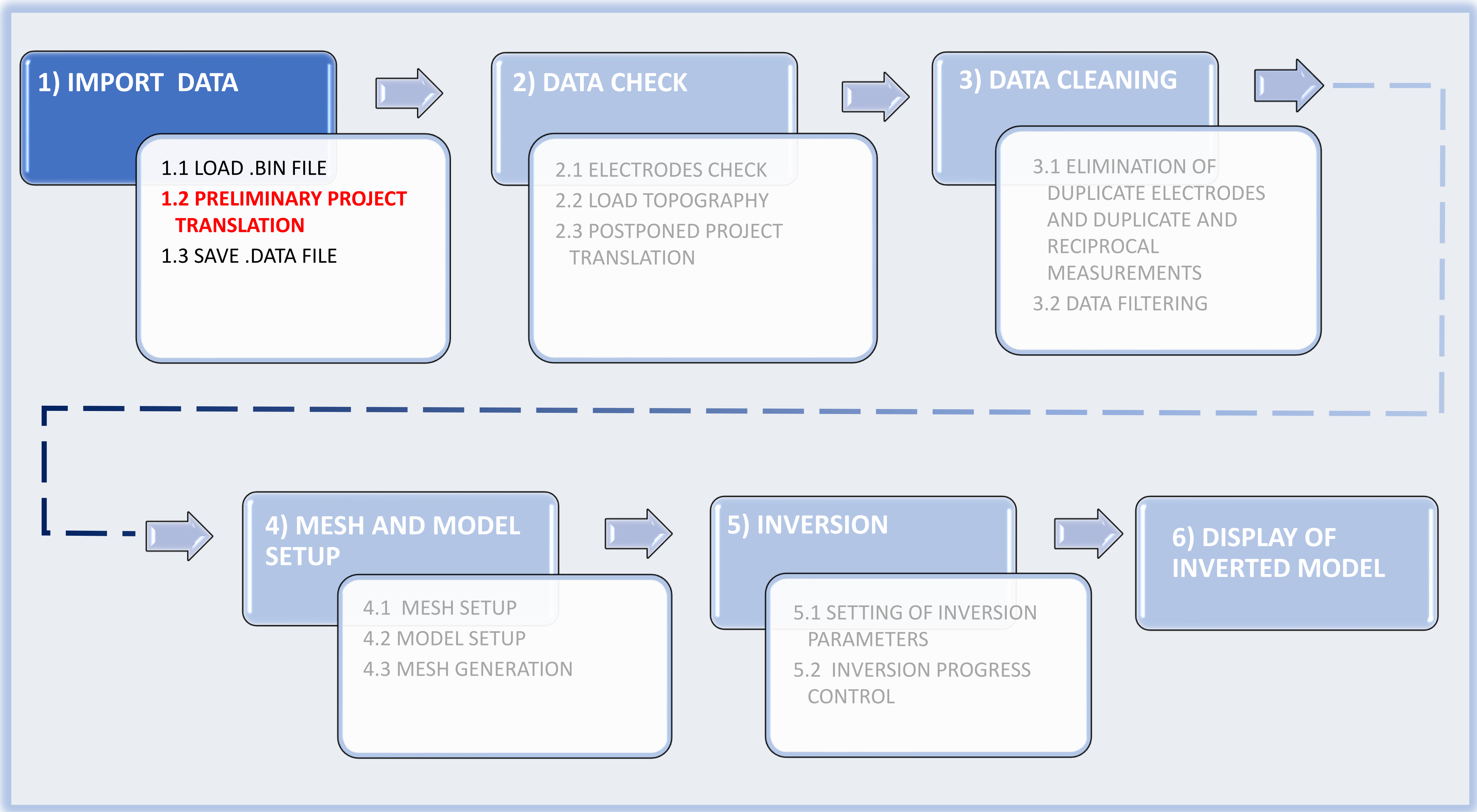
- Insert it in the conversion table, associating it at the ELECTRODE NUMBER = **-1**; in this case, ERTLab *Studio* will automatically identify it as a remote pole:

70	138	0	0	66.090	47201.970	87.550
71	140	0	0	66.510	47201.200	87.870
72	142	0	0	66.740	47200.190	88.260
-1	9315	7181	178	15.660	47181.190	78.420

Random coordinates

ERTLab *Studio*

WORKFLOW CHART FOR ERT DATA PROCESSING

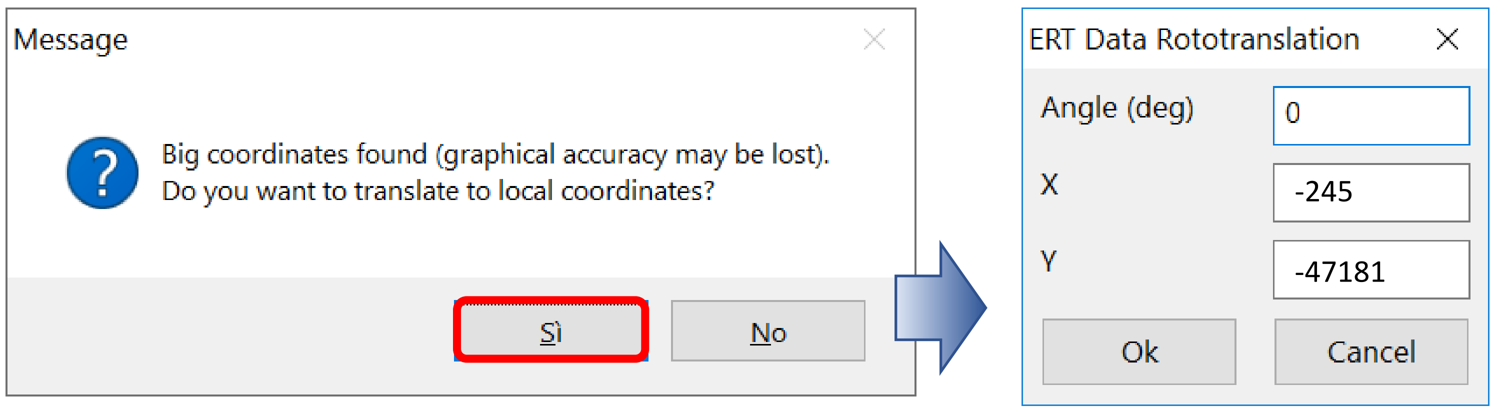


STEP 1: IMPORT DATA

1.2 Preliminary Project translation

If the loaded file includes electrodes with geographic coordinates (UTM), ERTLab *Studio* suggests to switch to a *Local Reference System*, shifting the system closer to the origin of the reference axes (near X=0, Y=0); this allows a good manage of data display even using not particularly performing calculators.

The optimal **TRANSLATION** values are automatically calculated and suggested by ERTLab *Studio.*



At the end of the processing, it is necessary to perform the ANTITRANSLATION (X and Y values with inverted sign, in this case +245 e +47181) to return the system to the exact coordinates.

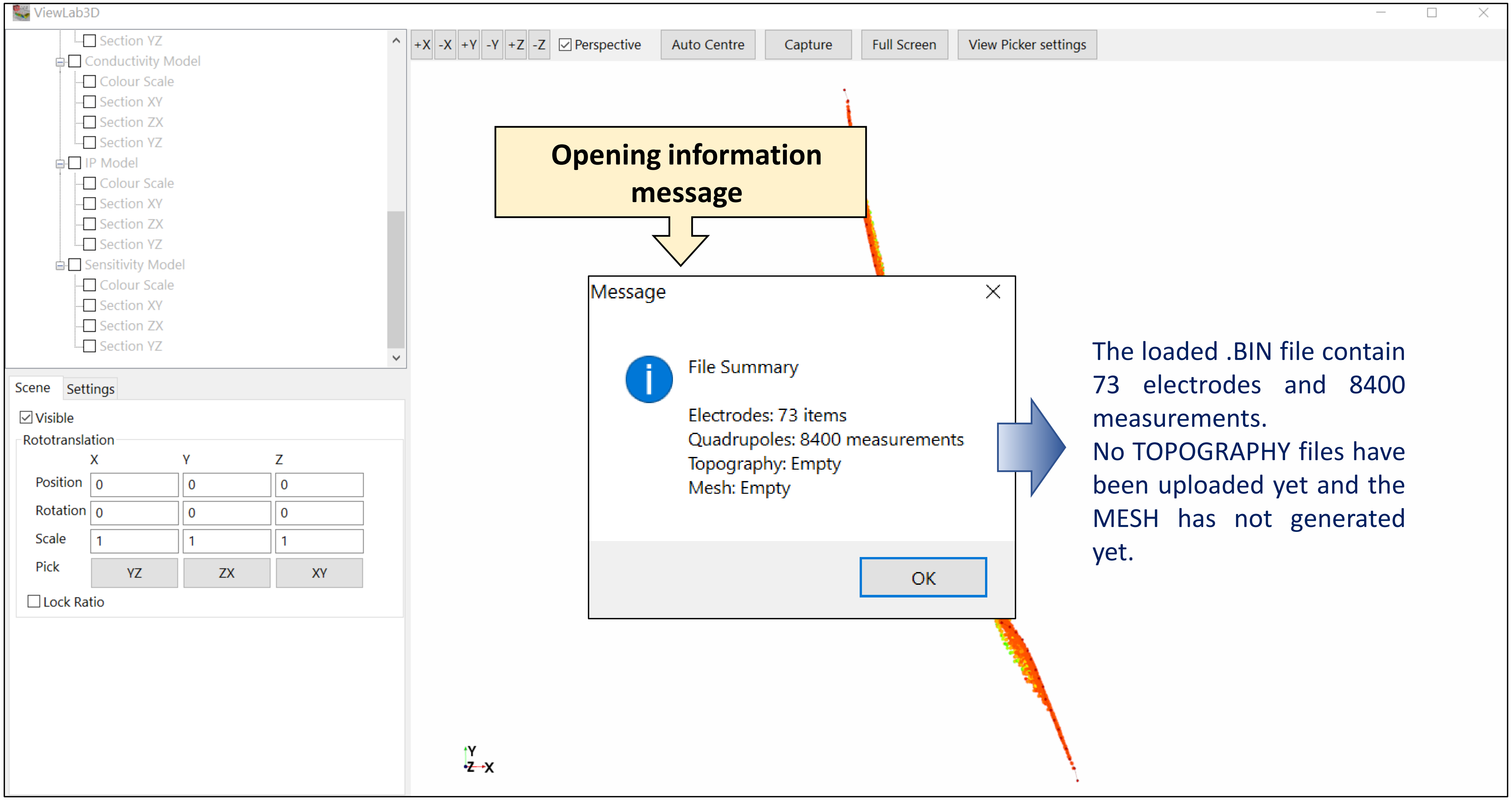
If a TOPOGRAPHY file has to be upload to the project, it must also be subject to the same translation. In this case, there are two ways to do this:

- Apply **automatic translation** to the project at this step and subsequently translate the topography using the proper tool, setting the SAME X and Y translation values (Paragraph 2.3);
- DO NOT apply automatic translation to the project at this step (click CANCEL) and translate topography and project together subsequently (Paragraph 2.3)

STEP 1: IMPORT DATA

1.2 Preliminary Project translation

When .BIN file is open, an information window summarizes the main features of the file.



The loaded .BIN file contain 73 electrodes and 8400 measurements.
No TOPOGRAPHY files have been uploaded yet and the MESH has not generated yet.

ERTLab *Studio*

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- **1.3 SAVE .DATA FILE**

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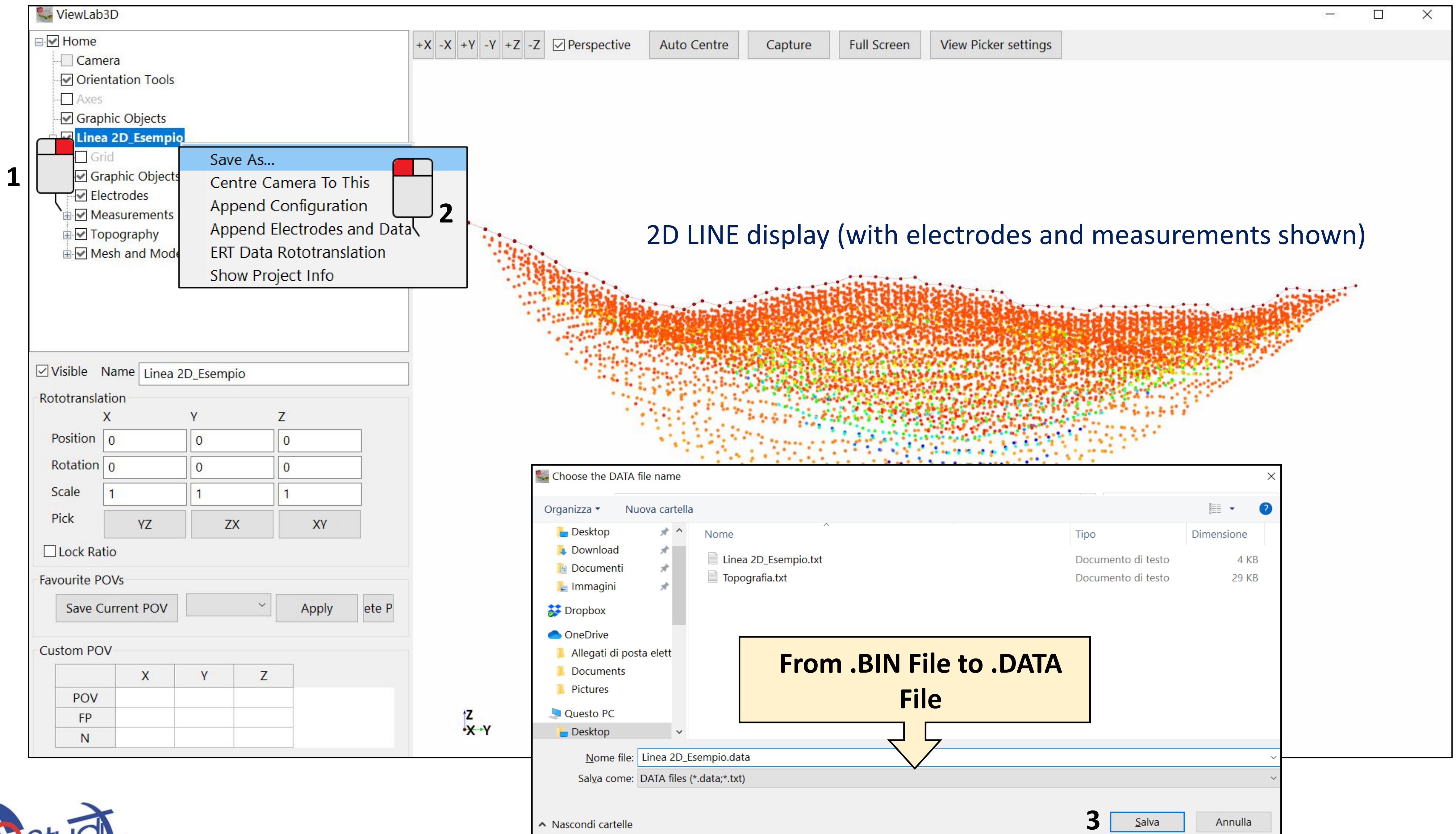
6) DISPLAY OF INVERTED MODEL

STEP 1: IMPORT DATA

1.3 Save .DATA file

From this point on, it is possible to save the file as .DATA File. To reopen this file later, use *Load* on the file upload screen and no longer *Load Bin*.



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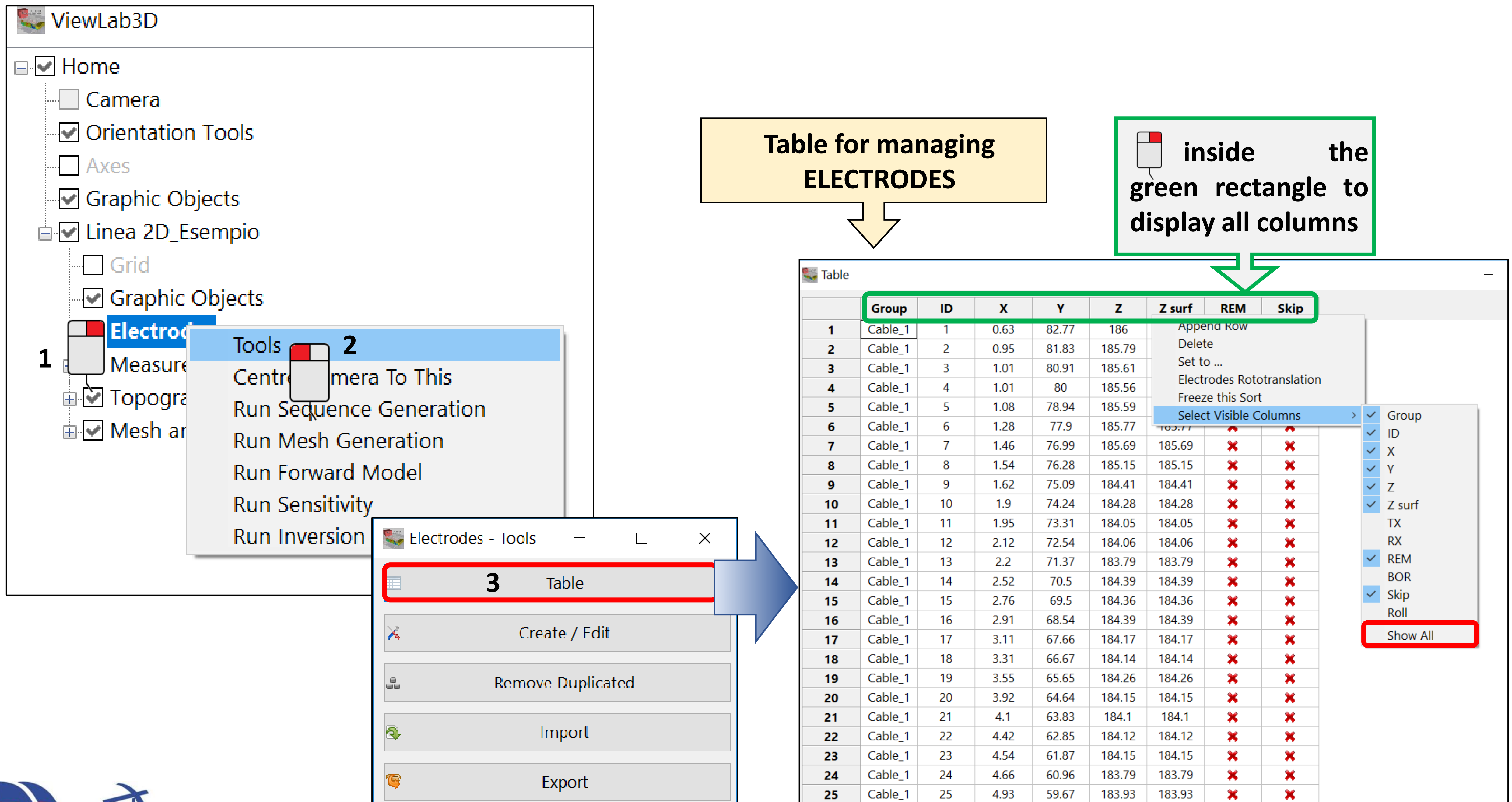
STEP 2: DATA CHECK

2.1 Electrodes check

Before proceeding with the next steps, it is advisable to check the electrodes and modify any incorrect information.



STEP 2: DATA CHECK

2.1 Electrodes check

Table

	Group	ID	X	Y	Z	Z surf	TX	RX	REM	BOR	Skip	Roll
1	Cable_1	1	0.63	82.77	186	186	✔	✔	✖	✖	✖	✖
2	Cable_1	2	0.95	81.83	185.79	185.79	✔	✔	✖	✖	✖	✖
3	Cable_1	3	1.01	80.91	185.61	185.61	✔	✔	✖	✖	✖	✖
4	Cable_1	4	1.01	80	185.56	185.56	✔	✔	✖	✖	✖	✖
5	Cable_1	5	1.08	78.94	185.59	185.59	✔	✔	✖	✖	✖	✖
6	Cable_1	6	1.28	77.9	185.77	185.77	✔	✔	✖	✖	✖	✖
7	Cable_1	7	1.46	76.99	185.69	185.69	✔	✔	✖	✖	✖	✖
8	Cable_1	8	1.54	76.28	185.15	185.15	✔	✔	✖	✖	✖	✖
9	Cable_1	9	1.62	75.09	184.41	184.41	✔	✔	✖	✖	✖	✖
10	Cable_1	10	1.9	74.24	184.28	184.28	✔	✔	✖	✖	✖	✖
11	Cable_1	11	1.95	73.31	184.05	184.05	✔	✔	✖	✖	✖	✖
12	Cable_1	12	2.12	72.54	184.06	184.06	✔	✔	✖	✖	✖	✖
13	Cable_1	13	2.2	71.37	183.79	183.79	✔	✔	✖	✖	✖	✖

- **Group**: cable name.
- **ID**: it is a counter that is used to identify each element of the group. It is a not editable column. It's not possible to associate the same 'ID' to more than one electrode of the same group, but two or more electrodes of different groups can have the same 'ID'.
- **X,Y,Z**: Coordinate of the electrodes in the space. It is possible to change the value of X/Y/Z by double-clicking the proper box.
- **Zsurf**: Z coordinate of the surface (if electrodes are positioned on the surface of the investigated area the Z and the Zsurf have the same value). It is possible to change the value by double-clicking the proper box.

STEP 2: DATA CHECK

2.1 Electrodes check

Table

	Group	ID	X	Y	Z	Z surf	TX	RX	REM	BOR	Skip	Roll
1	Cable_1	1	0.63	82.77	186	186	✔	✔	✖	✖	✖	✖
2	Cable_1	2	0.95	81.83	185.79	185.79	✔	✔	✖	✖	✖	✖
3	Cable_1	3	1.01	80.91	185.61	185.61	✔	✔	✖	✖	✖	✖
4	Cable_1	4	1.01	80	185.56	185.56	✔	✔	✖	✖	✖	✖
5	Cable_1	5	1.08	78.94	185.59	185.59	✔	✔	✖	✖	✖	✖
6	Cable_1	6	1.28	77.9	185.77	185.77	✔	✔	✖	✖	✖	✖
7	Cable_1	7	1.46	76.99	185.69	185.69	✔	✔	✖	✖	✖	✖
8	Cable_1	8	1.54	76.28	185.15	185.15	✔	✔	✖	✖	✖	✖
9	Cable_1	9	1.62	75.09	184.41	184.41	✔	✔	✖	✖	✖	✖
10	Cable_1	10	1.9	74.24	184.28	184.28	✔	✔	✖	✖	✖	✖
11	Cable_1	11	1.95	73.31	184.05	184.05	✔	✔	✖	✖	✖	✖
12	Cable_1	12	2.12	72.54	184.06	184.06	✔	✔	✖	✖	✖	✖
13	Cable_1	13	2.2	71.37	183.79	183.79	✔	✔	✖	✖	✖	✖

• **TX:** if it is flagged with ✔ it means that the relative electrode work as transmitter. If it is flagged with ✖ , instead, the electrode works just as receiver. This occurs especially with not-polarizable electrodes, which would be damaged if they sent current.

• **RX**: : if it is flagged with ✔ it means that the relative electrode work as receiver. If it is flagged with ✖ , instead, the electrode works just as transmitter.

Generally, the electrodes works both as transmitters that as receivers, so both flags are ✔ by default. During the sequence generation, it is possible to choose which electrodes must work as transmitters and/or receivers (double click in the proper box to switch between ✔ flag and ✖ flag, and vice versa).

STEP 2: DATA CHECK

2.1 Electrodes check

Table

	Group	ID	X	Y	Z	Z surf	TX	RX	REM	BOR	Skip	Roll
1	Cable_1	1	0.63	82.77	186	186	✔	✔	✘	✘	✘	✘
2	Cable_1	2	0.95	81.83	185.79	185.79	✔	✔	✘	✘	✘	✘
3	Cable_1	3	1.01	80.91	185.61	185.61	✔	✔	✘	✘	✘	✘
4	Cable_1	4	1.01	80	185.56	185.56	✔	✔	✘	✘	✘	✘
5	Cable_1	5	1.08	78.94	185.59	185.59	✔	✔	✘	✘	✘	✘
6	Cable_1	6	1.28	77.9	185.77	185.77	✔	✔	✘	✘	✘	✘
7	Cable_1	7	1.46	76.99	185.69	185.69	✔	✔	✘	✘	✘	✘
8	Cable_1	8	1.54	76.28	185.15	185.15	✔	✔	✘	✘	✘	✘
9	Cable_1	9	1.62	75.09	184.41	184.41	✔	✔	✘	✘	✘	✘
10	Cable_1	10	1.9	74.24	184.28	184.28	✔	✔	✘	✘	✘	✘
11	Cable_1	11	1.95	73.31	184.05	184.05	✔	✔	✘	✘	✘	✘
12	Cable_1	12	2.12	72.54	184.06	184.06	✔	✔	✘	✘	✘	✘
13	Cable_1	13	2.2	71.37	183.79	183.79	✔	✔	✘	✘	✘	✘

- **REM**: flag of remote electrode. All electrodes have the ✘ symbol, except the electrode relative to the remote pole, which is instead identified by the ✔ . It is possible to change the flag by double-clicking the proper box.

If the remote pole was not inserted in the conversion table file (Paragraph 1.1), check the proper box with the ✔ flag before proceeding with the measurements filtering.

- **BOR:** during sequence generation, it is possible to identify electrodes that work in hole and those placed on the surface. If the *Bor* flag is with the ✘ symbol, it means that the relative electrode belongs to a borehole survey (and *Zsurf* is different from *Z*); if it is flagged with the ✔ symbol, instead, the electrode is on the surface.

STEP 2: DATA CHECK

2.1 Electrodes check

Table

	Group	ID	X	Y	Z	Z surf	TX	RX	REM	BOR	Skip	Roll
1	Cable_1	1	0.63	82.77	186	186	✓	✓	✗	✗	✗	✗
2	Cable_1	2	0.95	81.83	185.79	185.79	✓	✓	✗	✗	✗	✗
3	Cable_1	3	1.01	80.91	185.61	185.61	✓	✓	✗	✗	✓	✗
4	Cable_1	4	1.01	80	185.56	185.56	✓	✓	✗	✗	✗	✗
5	Cable_1	5	1.08	78.94	185.59	185.59	✓	✓	✗	✗	✗	✗
6	Cable_1	6	1.28	77.9	185.77	185.77	✓	✓	✗	✗	✓	✗
7	Cable_1	7	1.46	76.99	185.69	185.69	✓	✓	✗	✗	✓	✗
8	Cable_1	8	1.54	76.28	185.15	185.15	✓	✓	✗	✗	✗	✗
9	Cable_1	9	1.62	75.09	184.41	184.41	✓	✓	✗	✗	✗	
10	Cable_1	10	1.9	74.24	184.28	184.28	✓	✓	✗	✗	✗	
11	Cable_1	11	1.95	73.31	184.05	184.05	✓	✓	✗	✗	✗	
12	Cable_1	12	2.12	72.54	184.06	184.06	✓	✓	✗	✗	✗	
13	Cable_1	13	2.2	71.37	183.79	183.79	✓	✓	✗	✗	✗	

Append Row
Delete
Set to ...
Electrodes Rototranslation
Skip Measurements using skipped Electrodes
Freeze this Sort
Select Visible Columns

- **Skip:** If one or more electrodes did not work during the acquisition, it is possible to delete the proper measurements following the steps described here:
  - Mark the *Skip* box of the electrodes with the ✓ flag, double-clicking the proper box (in the example, electrodes 3, 6 and 7);
  - Right-click anywhere inside the electrodes table;
  - Click on *Skip Measurements using skipped electrodes*; with this function the measurements involving the electrodes marked by the flag ✓ are not used for inversion, but they are still in the dataset (they are not used for the inversion but they are not deleted, so it is possible to retrieve them later).

The same procedure, if applied during the <u>sequence generation</u>, allows to exclude some electrodes already during data acquisition.

STEP 2: DATA CHECK

2.1 Electrodes check

Table

	Group	ID	X	Y	Z	Z surf	TX	RX	REM	BOR	Skip	Roll
1	Cable_1	1	0.63	82.77	186	186	✓	✓	✗	✗	✗	✗
2	Cable_1	2	0.95	81.83	185.79	185.79	✓	✓	✗	✗	✗	✗
3	Cable_1	3	1.01	80.91	185.61	185.61	✓	✓	✗	✗	✗	✗
4	Cable_1	4	1.01	80	185.56	185.56	✓	✓	✗	✗	✗	✗
5	Cable_1	5	1.08	78.94	185.59	185.59	✓	✓	✗	✗	✗	✗
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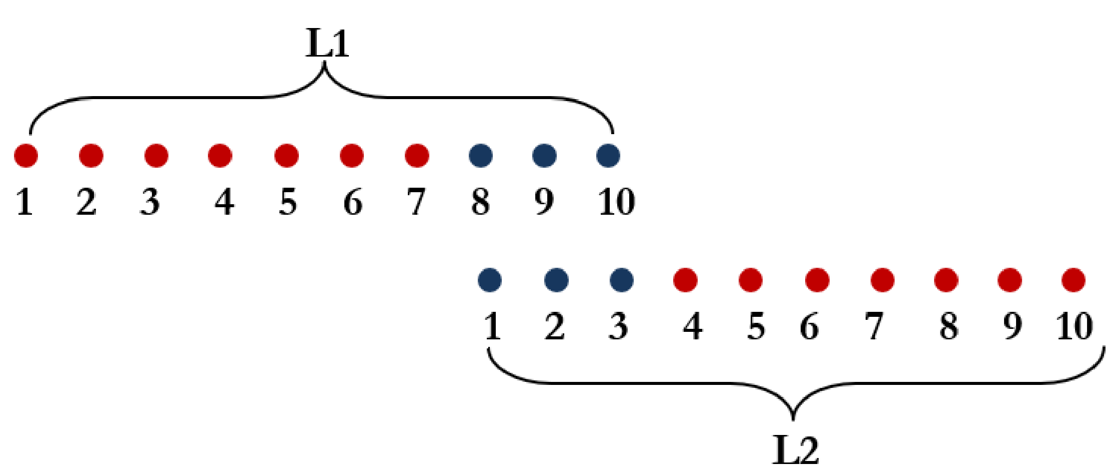
7	Cable_1	7	1.46	76.99	185.69	185.69	✓	✓	✗	✗	✗	✗
8	Cable_1	8	1.54	76.28	185.15	185.15	✓	✓	✗	✗	✗	✗
9	Cable_1	9	1.62	75.09	184.41	184.41	✓	✓	✗	✗	✗	✗
10	Cable_1	10	1.9	74.24	184.28	184.28	✓	✓	✗	✗	✗	✗
11	Cable_1	11	1.95	73.31	184.05	184.05	✓	✓	✗	✗	✗	✗
12	Cable_1	12	2.12	72.54	184.06	184.06	✓	✓	✗	✗	✗	✗
13	Cable_1	13	2.2	71.37	183.79	183.79	✓	✓	✗	✗	✗	✗

- **ROLL**: if during the acquisition the roll-along method was adopted, the electrode commons at two consecutive lines are marked with ✓ symbol , otherwise they are marked as ✗ . Electrodes that remain in place (in blue in the figure below) are marked by the Roll tag <u>during the sequence generation</u>.



<u>Example of Roll-Along Method acquisition</u>

After the L1 line is acquired, the L2 line is positioned moving the electrodes from 1 to 7 and leaving the other electrodes in place. So the electrodes 8, 9 and 10 of Line 1 become the electrodes 1, 2 and 3 for line 2 (here, L1 and L2 are represented apart but they are actually on the same line and the electrodes in blue are not moved).

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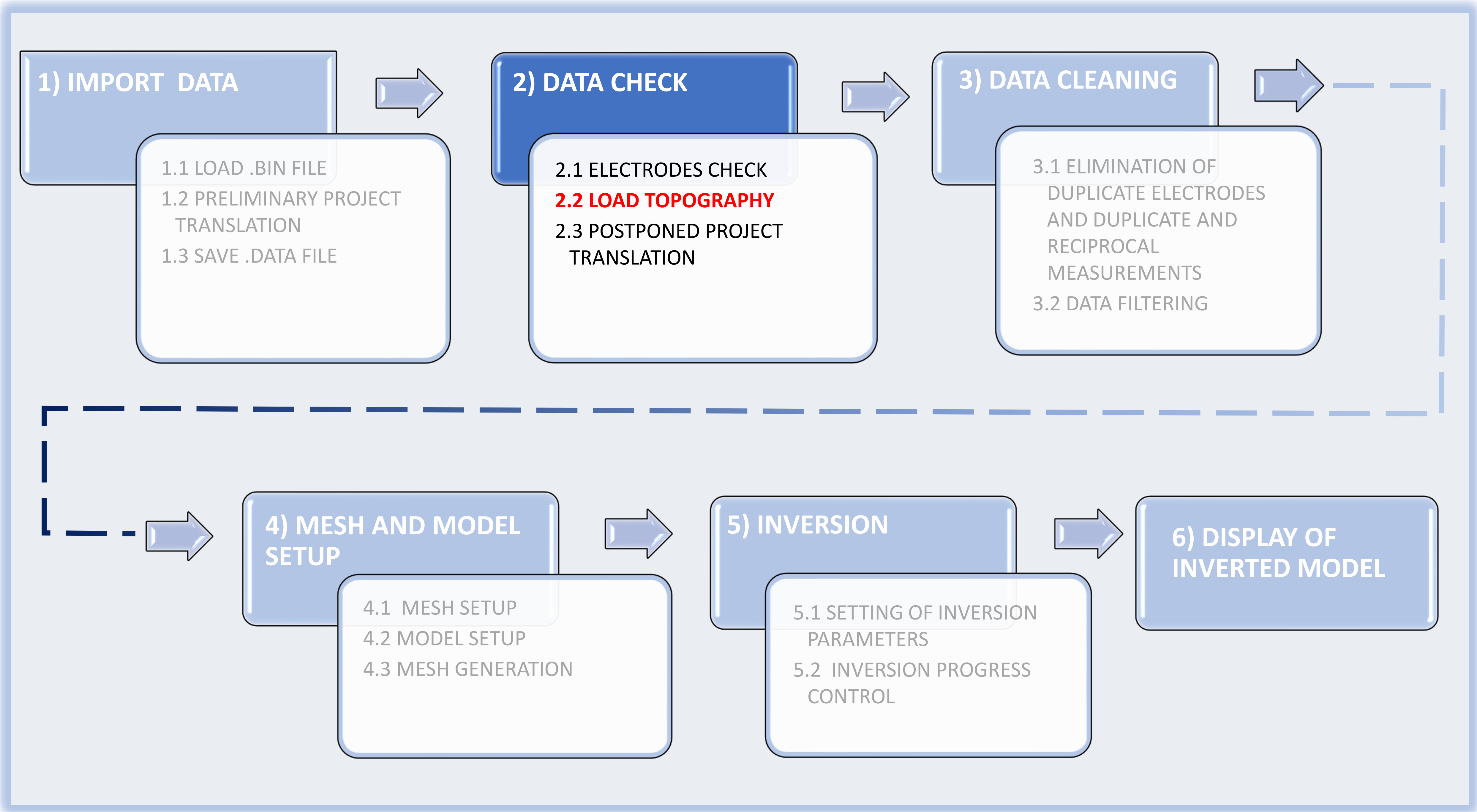
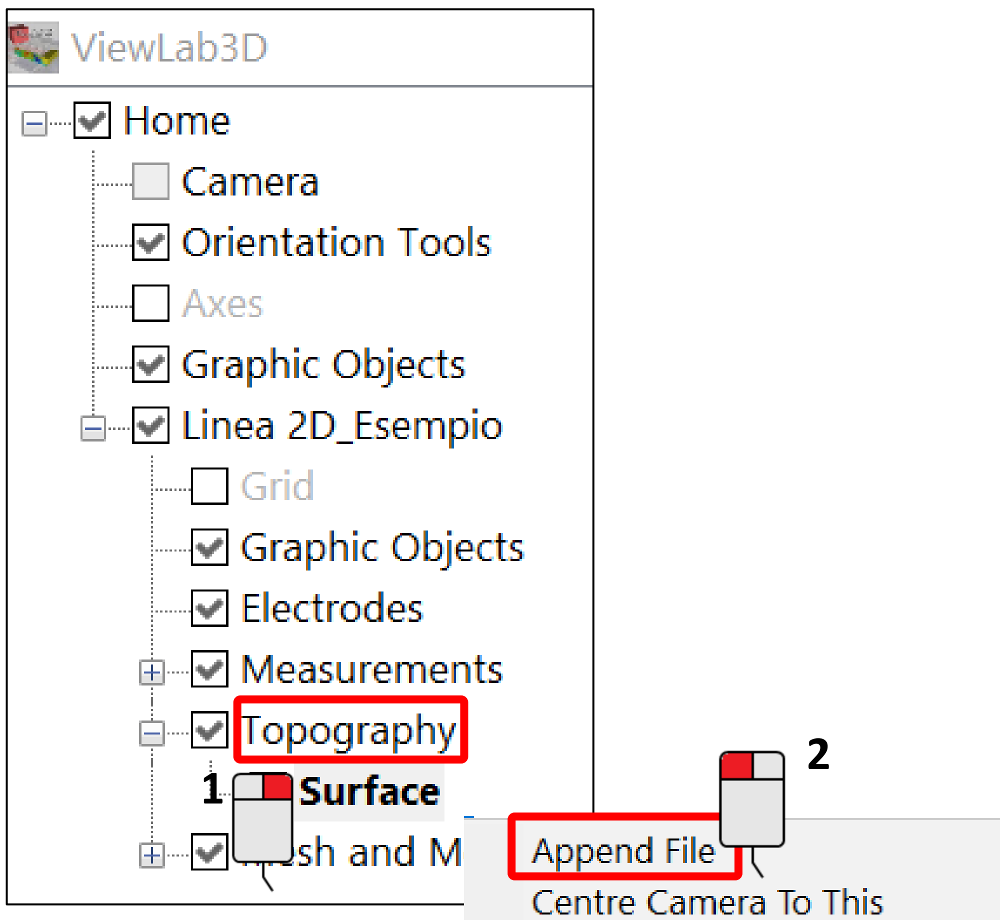
WORKFLOW CHART FOR ERT DATA PROCESSING



STEP 2: DATA CHECK

2.2 Load Topography

It is possible to add a topography file, which allows a more correct reconstruction of the 3D volume and processing of data, especially in non-flat contexts.



topography file must be a .txt file with 3 columns :
Coordinate X **Coordinate Y** **Coordinate Z**

Topografia.txt - Blocco note

File Modifica Formato Visualizza ?

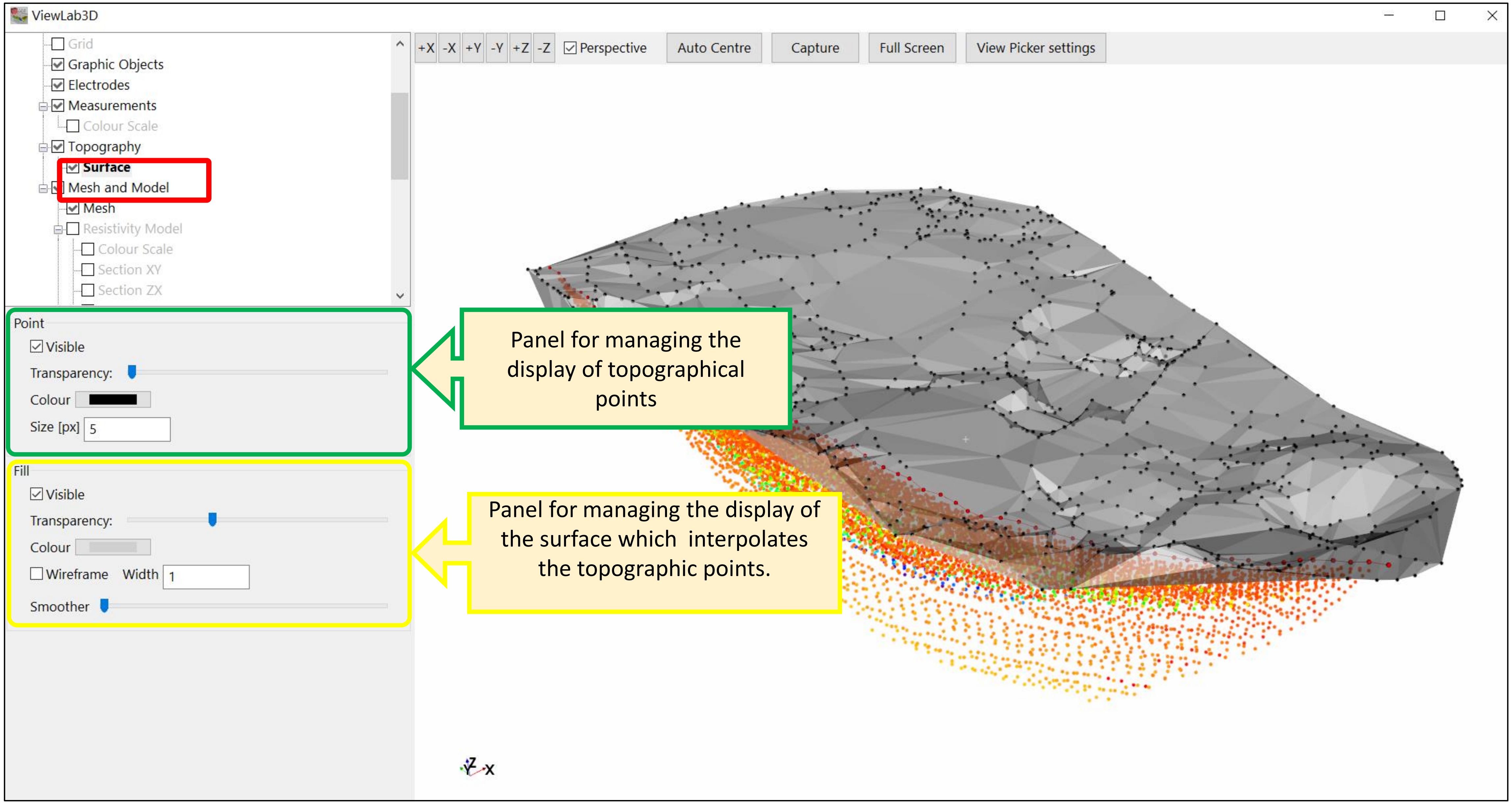
138.51	245.02	-21.87
135.09	245.02	-21.75
137.92	241.87	-21.74
134.91	241.92	-21.71
141.99	242.77	-21.97
143.53	240.73	-21.96
148.83	241.82	-22.35
149.10	243.75	-22.45
154.22	243.40	-22.82
154.48	241.45	-22.74
140.29	237.78	-21.76
137.13	233.34	-21.60
131.34	233.40	-21.66
131.55	224.39	-21.28
135.86	222.56	-21.08
133.82	216.60	-20.82
131.40	216.76	-20.96
129.14	211.28	-20.67
130.63	210.09	-20.50

Example of Topography file *(in local coordinates)*

STEP 2: DATA CHECK

2.2 Load Topography

It is possible to manage the display of the topography through the tools in the ***Surface*** sub-node.

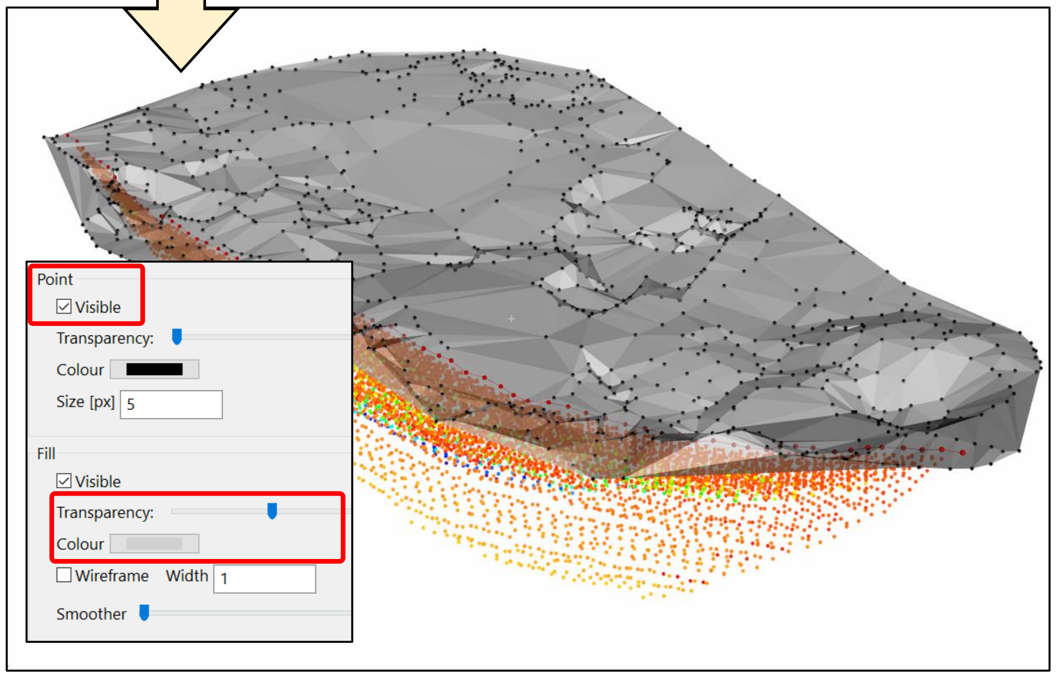


STEP 2: DATA CHECK

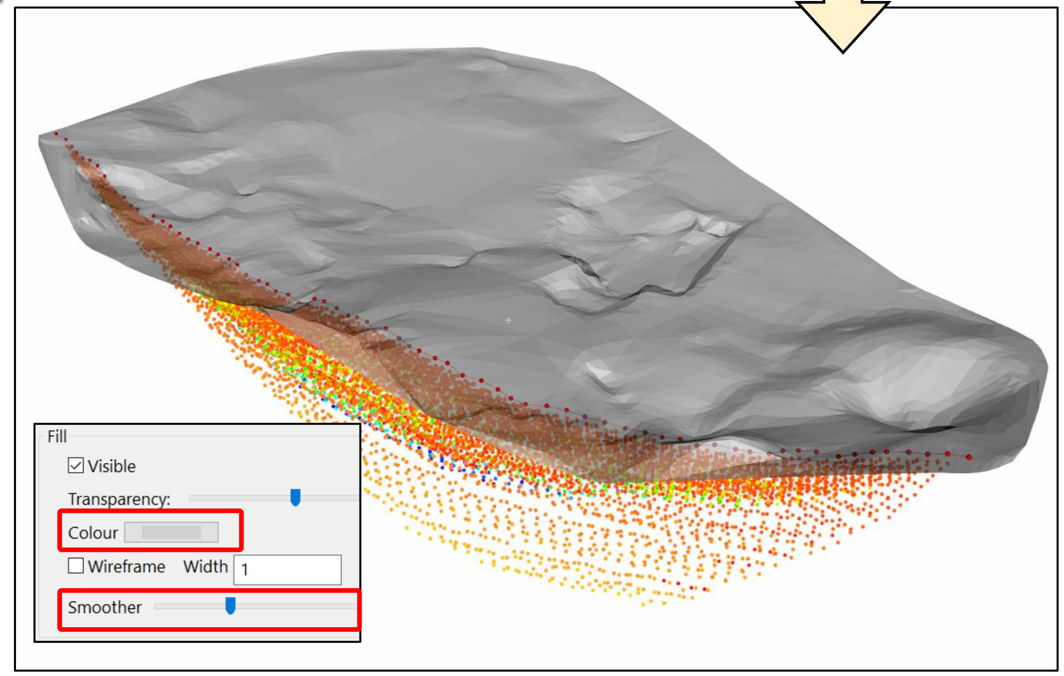
2.2 Load Topography

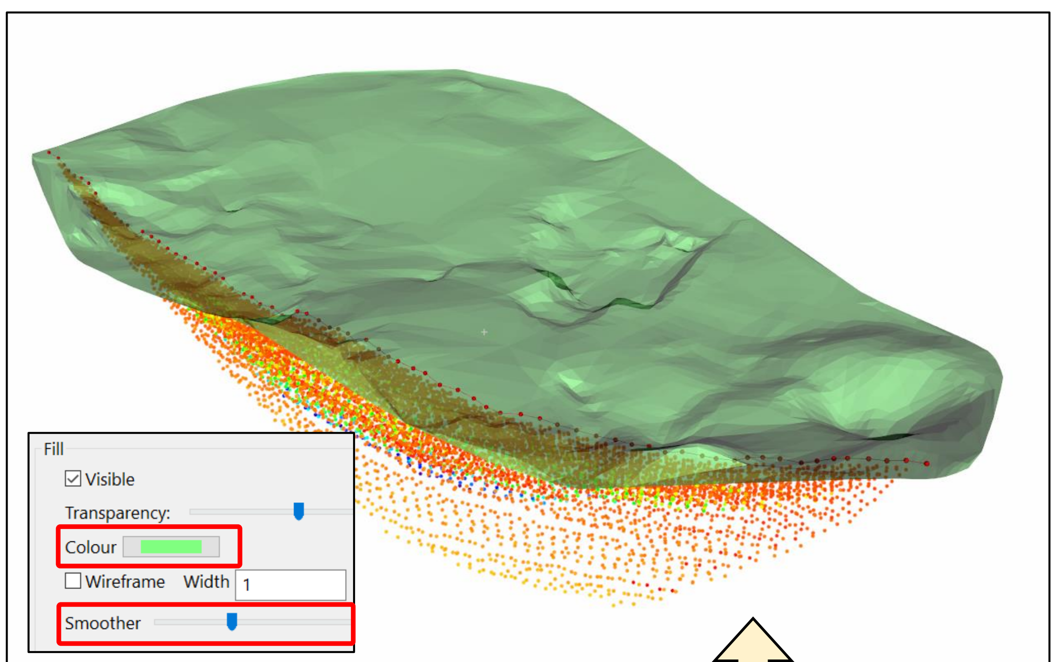
Examples

Topography with **gray surface** with medium transparency and topographical **points displayed**

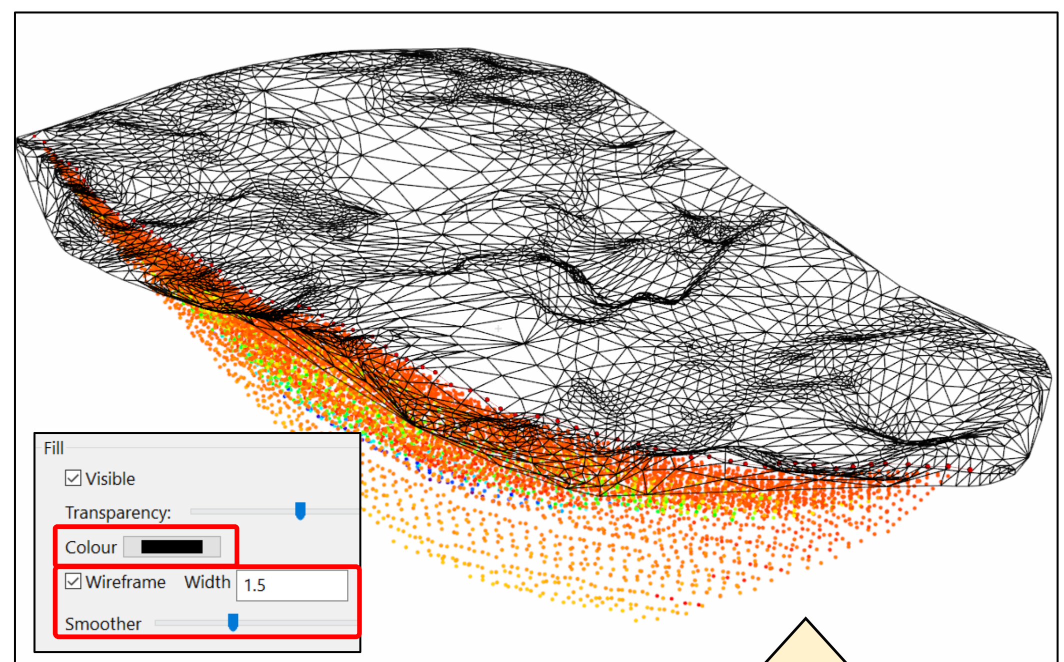


Topography with **gray surface** with **smooth** and medium **transparency**





Topography with **green surface**, with **smooth** and medium level of **transparency**



Topography with black **wireframe surface,** with **smooth** applied and medium level of **transparency**

ERTLab *Studio*

WORKFLOW CHART FOR ERT DATA PROCESSING

1) IMPORT DATA

- 1.1 LOAD .BIN FILE
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- 1.3 SAVE .DATA FILE

2) DATA CHECK

- 2.1 ELECTRODES CHECK
- 2.2 LOAD TOPOGRAPHY
- **2.3 POSTPONED PROJECT TRANSLATION**

3) DATA CLEANING

- 3.1 ELIMINATION OF DUPLICATE ELECTRODES AND DUPLICATE AND RECIPROCAL MEASUREMENTS
- 3.2 DATA FILTERING

4) MESH AND MODEL SETUP

- 4.1 MESH SETUP
- 4.2 MODEL SETUP
- 4.3 MESH GENERATION

5) INVERSION

- 5.1 SETTING OF INVERSION PARAMETERS
- 5.2 INVERSION PROGRESS CONTROL

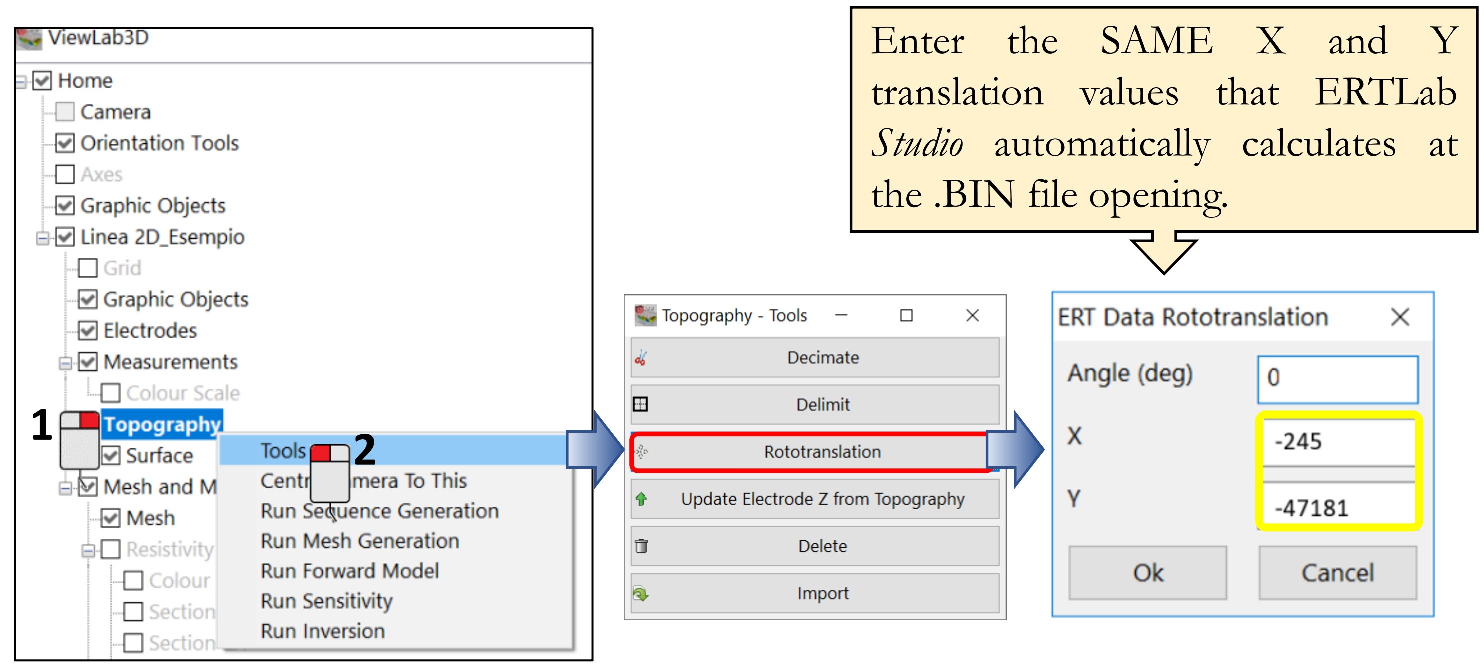
6) DISPLAY OF INVERTED MODEL

STEP 2: DATA CHECK

2.3 Post-poned project translation

After the topography is loaded, if it is in geographic coordinates (UTM), ERTLab *Studio* suggests the transition to a **local reference system**, shifting the system closer to the origin of the reference axes (near X=0, Y=0); this allows a reactive management of data even with the use of a not very performing calculators.

- **IF** during the loading of the .BIN File has been chosen to apply the **AUTOMATIC TRANSLATION** of the system, it is necessary to apply the SAME TRANSLATION also to TOPOGRAPHY.



- **IF** during the loading of the .BIN file has been chosen to **NOT** apply the **AUTOMATIC TRANSLATION** of the system, now it is possible to move the entire project jointly. To do that:
    - SAVE the current project (with electrodes check and the topography loading done);
    - CLOSE the project;
    - LOAD again the project→ at this point, ERTLab *Studio* suggests the AUTOMATIC TRANSLATION again, based on the coordinates of the project and the topography loaded together;
    - APPLY THE SUGGESTED AUTOTRANSLATION.

Whatever the translation mode is perform, at the end of processing it is possible to make an ANTITRANSLATION (values of X and Y with inverted sign) to return the system to the original coordinates.

ERTLab *Studio*

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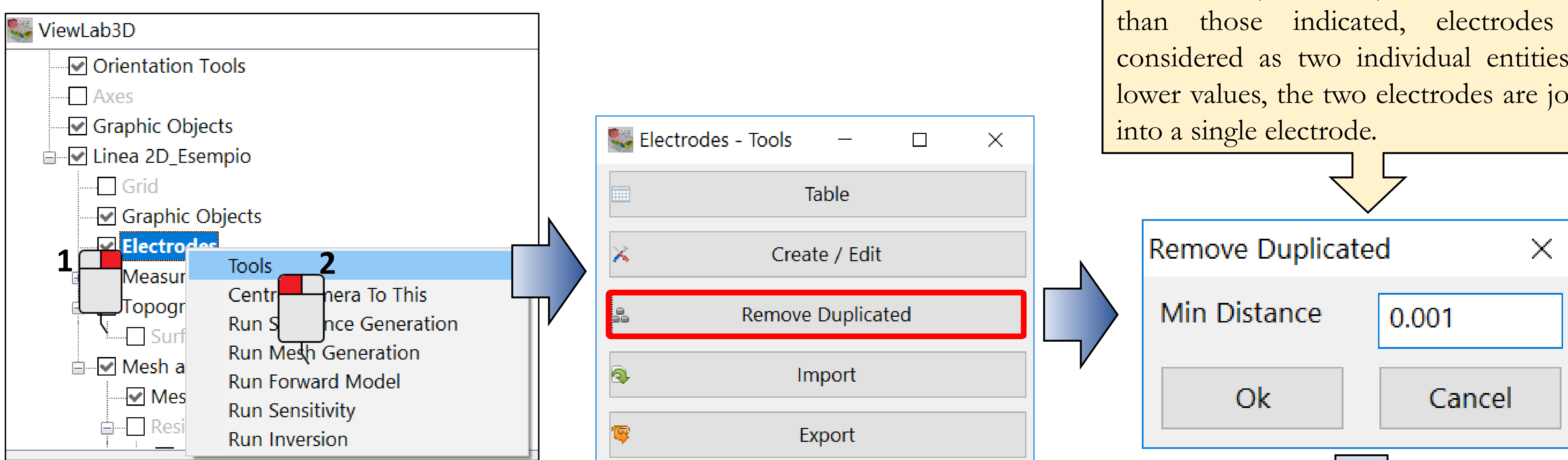
STEP 3: DATA CLEANING

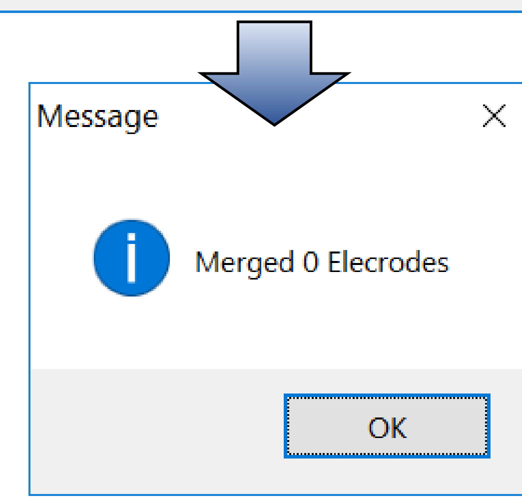
3.1 Elimination of duplicate electrodes and duplicate and reciprocal measurements

DUPLICATED ELECTRODES → Electrodes with **same coordinates**.

They can result from a repetition during the record of the electrode positioning by the topographer (with a small difference between the two measurements) or from two 2D lines that intersect not at the same electrode.



Tolerance of the distance between two electrodes (in meters). At values higher than those indicated, electrodes are considered as two individual entities. At lower values, the two electrodes are joined into a single electrode.



No duplicate electrodes were found in this case

Do not delete duplicate electrodes does not cause errors in the inversion process, but it can make it more time consuming.

STEP 3: DATA CLEANING

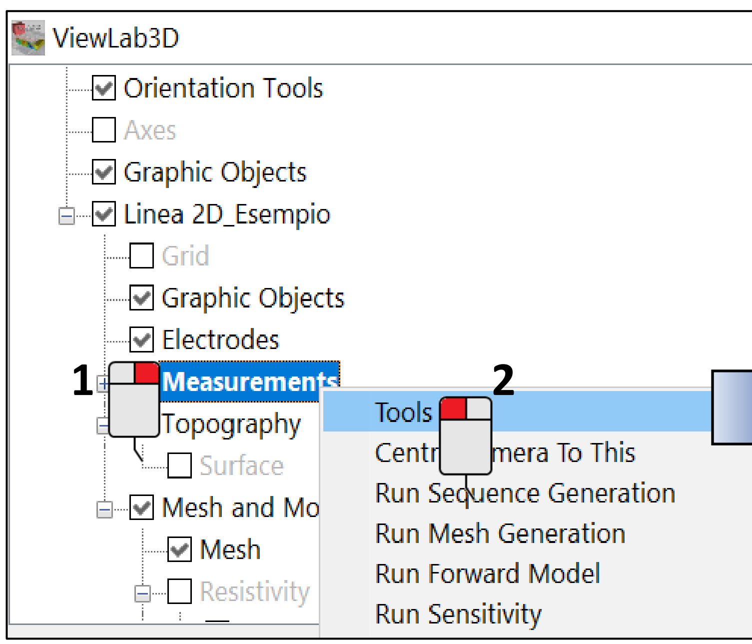
3.1 Elimination of duplicate electrodes and duplicate and reciprocal measurements

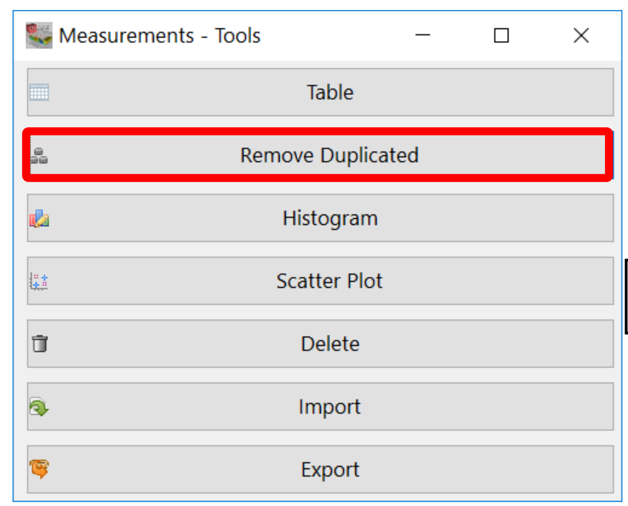
RECIPROCAL MEASUREMENTS→ Measurements with **Tx** and **Rx reversed.** Theoretically, they should give the same measure

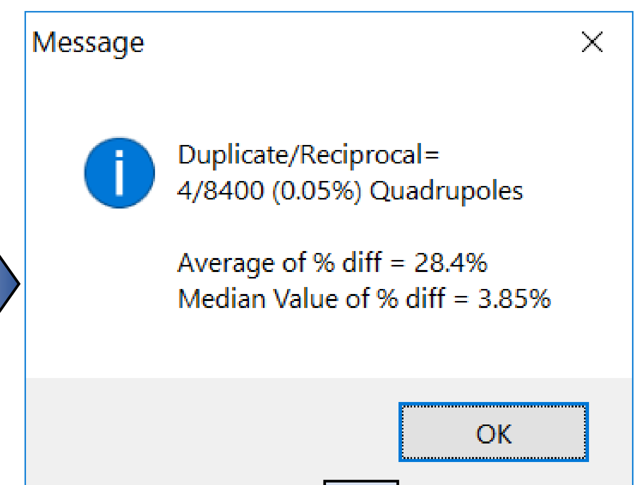
AB MN = BA MN
AB MN = BA NM
AB MN = AB NM
} **DUPLICATE MEASUREMENTS**

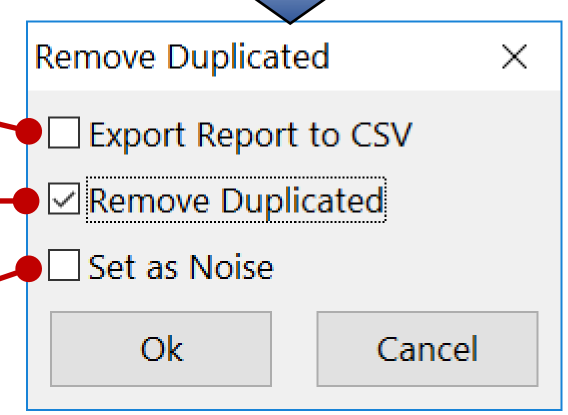
AB MN = MN AB → **RECIPROCAL MEASUREMENTS**
AB MN = NM AB
AB MN = MN BA
AB MN = NM BA
} **DUPLICATE OF RECIPROCAL MEASUREMENTS**

Information about the number of reciprocal quadrupoles and the % average of Apparent Resistivity









Export .CSV file with information about duplicate/reciprocal measurements

Removes reciprocal measurements from the dataset

Value that ERTLab will attribute to Rho noise % for the inversion (Paragraph 5.1)

ERTLab *Studio*

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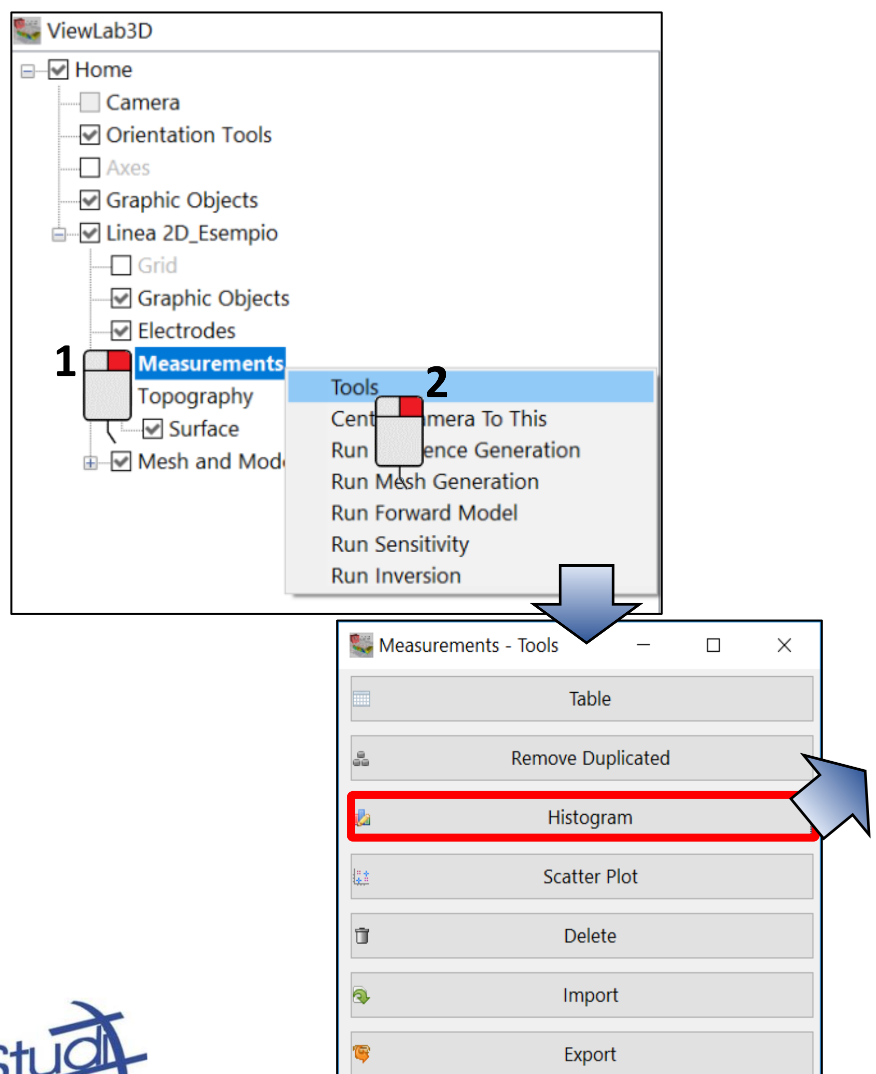
STEP 3: DATA CLEANING

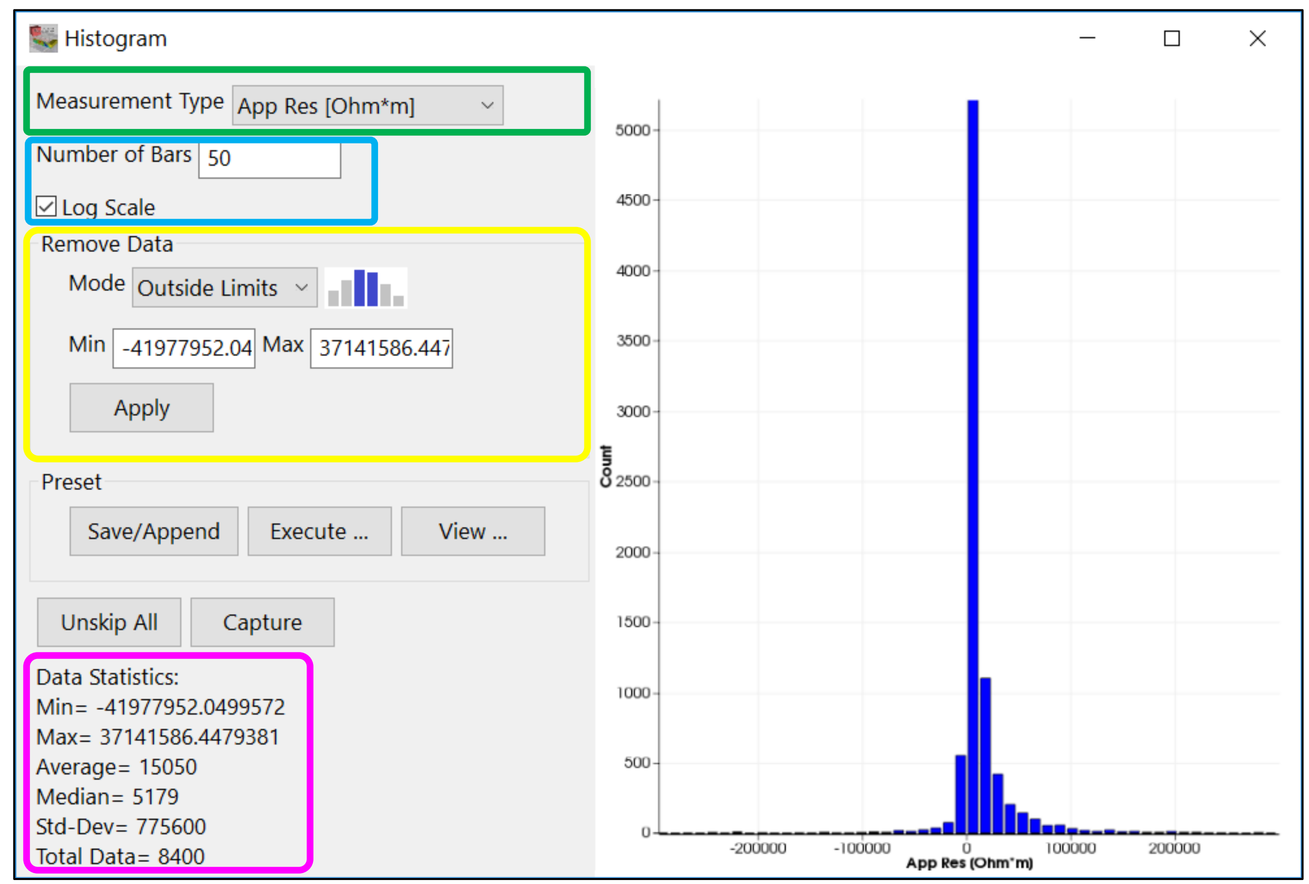
3.2 Data Filtering

It is possible to clean data following different approaches:

- **STATISTICAL ANALYSIS OF MEASURES** → By graphical representation of measurements (Histograms);
- **NUMERICAL ANALYSIS OF MEASURES** → By sorting measuremnts (increasing values, decreasing values, absolute value..);
- **GRAPHICAL ANALYSIS OF MEASURES** → Plotting data in 2D charts.

The first type is the most commonly used.





Choice of the type of measure to filter

Setting of mode and values for data filtering

Setting of histogram display mode

Statistical summary of data

STEP 3: DATA CLEANING

3.2 Data Filtering_Statistical Analysis

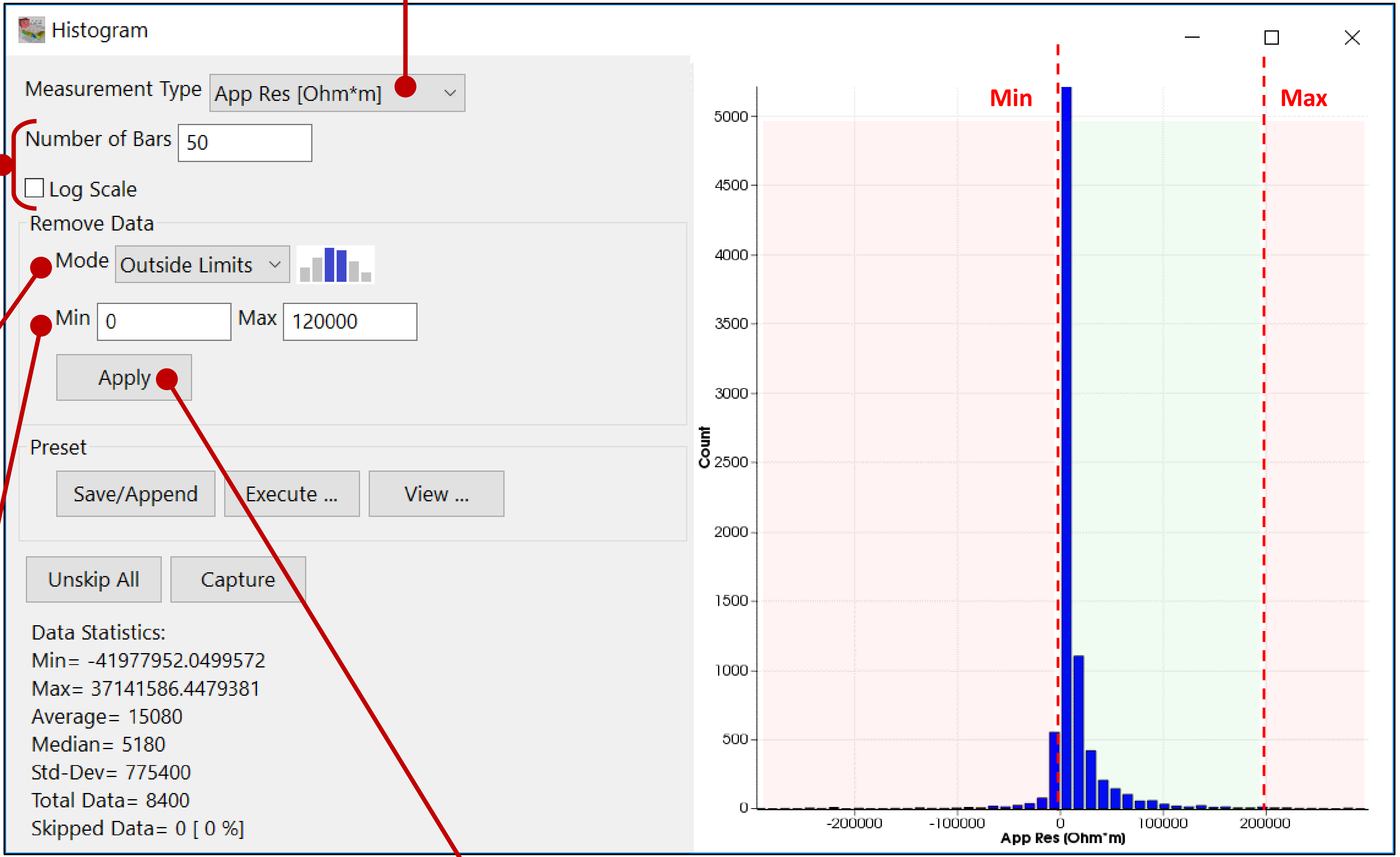
Example filtering *Apparent Resistivity:*

I. Select **App Res** (Ohm*m) from the drop-down menu.

II. Optionally increase the **number of bars** of the histogram and set the logarithmic display mode for a better representation of data distribution.

III. Select **Outside Limits** to filter data external to cut limits values (areas highlighted in red in the histogram) and preserve the INTERNAL data (area highlighted in green in the histogram);

IV. Write **cut values**, maximum, and minimum, basing on histogram trend;



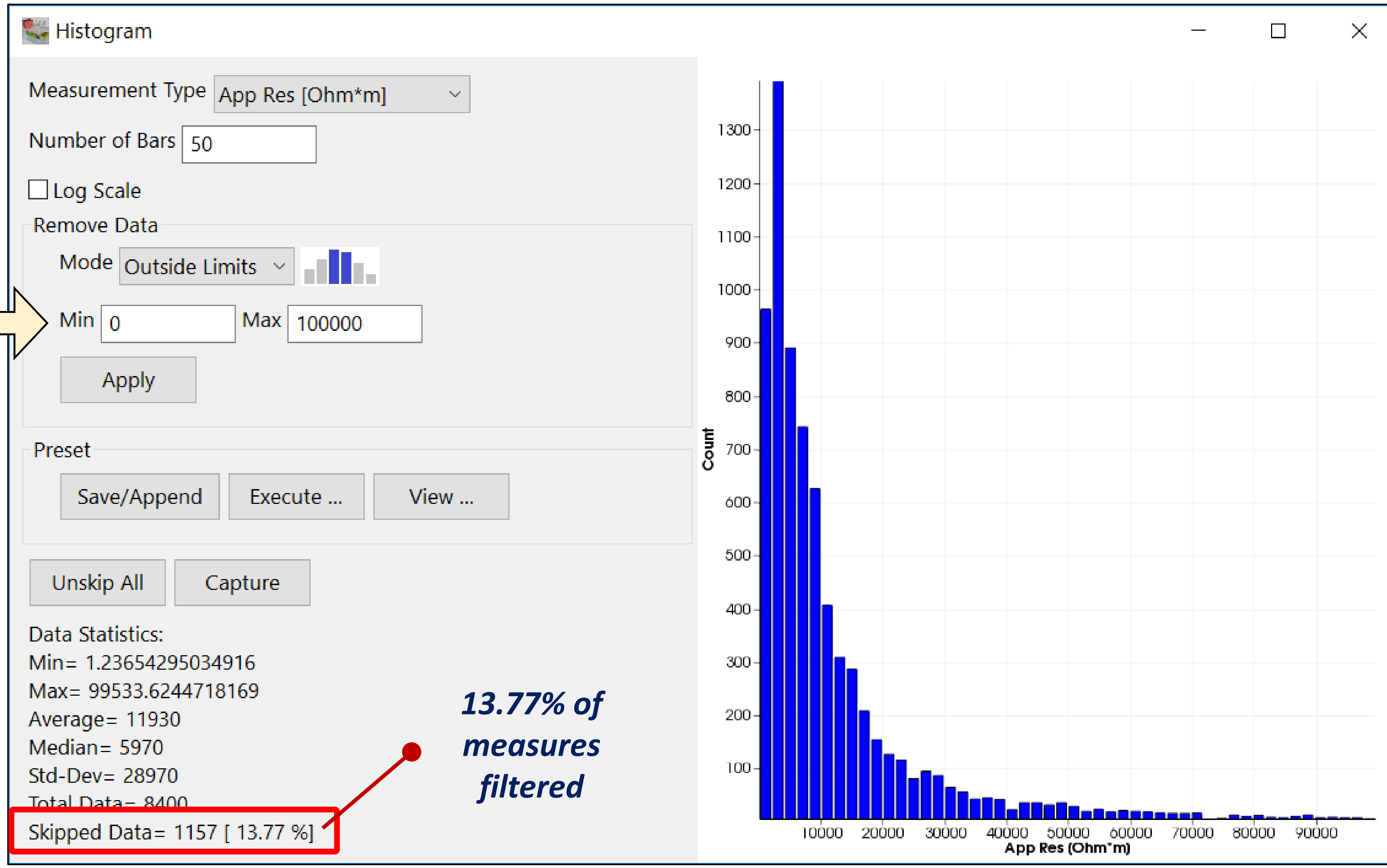
V. Click **Apply**

STEP 3: DATA CLEANING

3.2 Data Filtering_Statistical Analysis

VI. Check the quantity of deleted data after the application of filtering, in the *Statistical Summary* panel.

In this case, the values<0 were deleted because in a 2D line negative Apparent Resistivity values constitute noise



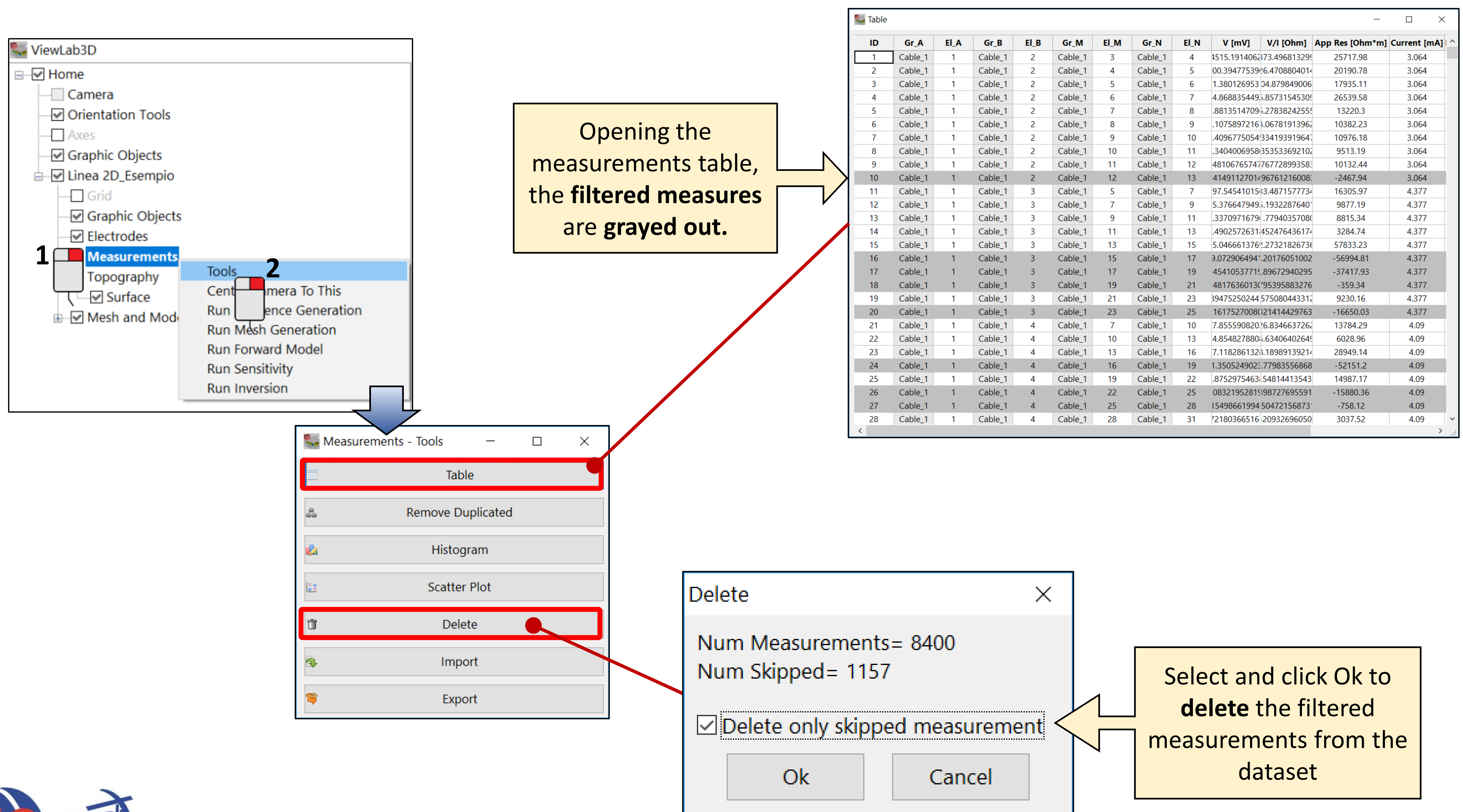
Repeat the steps for the other voices to filter, selecting them from the drop-down menu.

To filter the **Quality Factor q,** clean the percentage standard deviation data (**StdDev V/I %**)

STEP 3: DATA CLEANING

3.2 Data Filtering_Statistical Analysis

The filtered data has NOT been deleted from the dataset, but they will not be used for inversion. However, it is possible to delete them from the project.



ID	Gr_A	El_A	Gr_B	El_B	Gr_M	El_M	Gr_N	El_N	V [mV]	V/I [Ohm]	App Res [Ohm*m]	Current [mA]
1	Cable_1	1	Cable_1	2	Cable_1	3	Cable_1	4	515.1914062	73.49681329	25717.98	3.064
2	Cable_1	1	Cable_1	2	Cable_1	4	Cable_1	5	00.3947753	6.47088040	20190.78	3.064
3	Cable_1	1	Cable_1	2	Cable_1	5	Cable_1	6	1.380126953	04.879849006	17935.11	3.064
4	Cable_1	1	Cable_1	2	Cable_1	6	Cable_1	7	4.868835449	.857315453	26539.58	3.064
5	Cable_1	1	Cable_1	2	Cable_1	7	Cable_1	8	.8813514709	.278382425	13220.3	3.064
6	Cable_1	1	Cable_1	2	Cable_1	8	Cable_1	9	.1075897216	.0678191396	10382.23	3.064
7	Cable_1	1	Cable_1	2	Cable_1	9	Cable_1	10	.409677505	33419391964	10976.18	3.064
8	Cable_1	1	Cable_1	2	Cable_1	10	Cable_1	11	.340400695	3535336921	9513.19	3.064
9	Cable_1	1	Cable_1	2	Cable_1	11	Cable_1	12	481067657	76772899358	10132.44	3.064
10	Cable_1	1	Cable_1	2	Cable_1	12	Cable_1	13	414911270	96761216008	-2467.94	3.064
11	Cable_1	1	Cable_1	3	Cable_1	5	Cable_1	7	97.5454101	3.48715777	16305.97	4.377
12	Cable_1	1	Cable_1	3	Cable_1	7	Cable_1	9	5.376647949	.193228764	9877.19	4.377
13	Cable_1	1	Cable_1	3	Cable_1	9	Cable_1	11	.3370971679	.779403570	8815.34	4.377
14	Cable_1	1	Cable_1	3	Cable_1	11	Cable_1	13	.490257263	45247643617	3284.74	4.377
15	Cable_1	1	Cable_1	3	Cable_1	13	Cable_1	15	5.046661376	.273218267	57833.23	4.377
16	Cable_1	1	Cable_1	3	Cable_1	15	Cable_1	17	.072906494	.20176051002	-56994.81	4.377
17	Cable_1	1	Cable_1	3	Cable_1	17	Cable_1	19	454105377	.89672940295	-37417.93	4.377
18	Cable_1	1	Cable_1	3	Cable_1	19	Cable_1	21	481763601	95395883276	-359.34	4.377
19	Cable_1	1	Cable_1	3	Cable_1	21	Cable_1	23	9475250244	57508044331	9230.16	4.377
20	Cable_1	1	Cable_1	3	Cable_1	23	Cable_1	25	161752700	21414429763	-16650.03	4.377
21	Cable_1	1	Cable_1	4	Cable_1	7	Cable_1	10	7.855590820	6.83466372	13784.29	4.09
22	Cable_1	1	Cable_1	4	Cable_1	10	Cable_1	13	4.85482788	.634064026	6028.96	4.09
23	Cable_1	1	Cable_1	4	Cable_1	13	Cable_1	16	7.11828613	.18989139	28949.14	4.09
24	Cable_1	1	Cable_1	4	Cable_1	16	Cable_1	19	1.35052490	.77983556868	-52151.2	4.09
25	Cable_1	1	Cable_1	4	Cable_1	19	Cable_1	22	.875297546	.54814413543	14987.17	4.09
26	Cable_1	1	Cable_1	4	Cable_1	22	Cable_1	25	083219528	98727695591	-15880.36	4.09
27	Cable_1	1	Cable_1	4	Cable_1	25	Cable_1	28	15498661994	50472156873	-758.12	4.09
28	Cable_1	1	Cable_1	4	Cable_1	28	Cable_1	31	2180366516	20932696050	3037.52	4.09

ERTLab *Studio*

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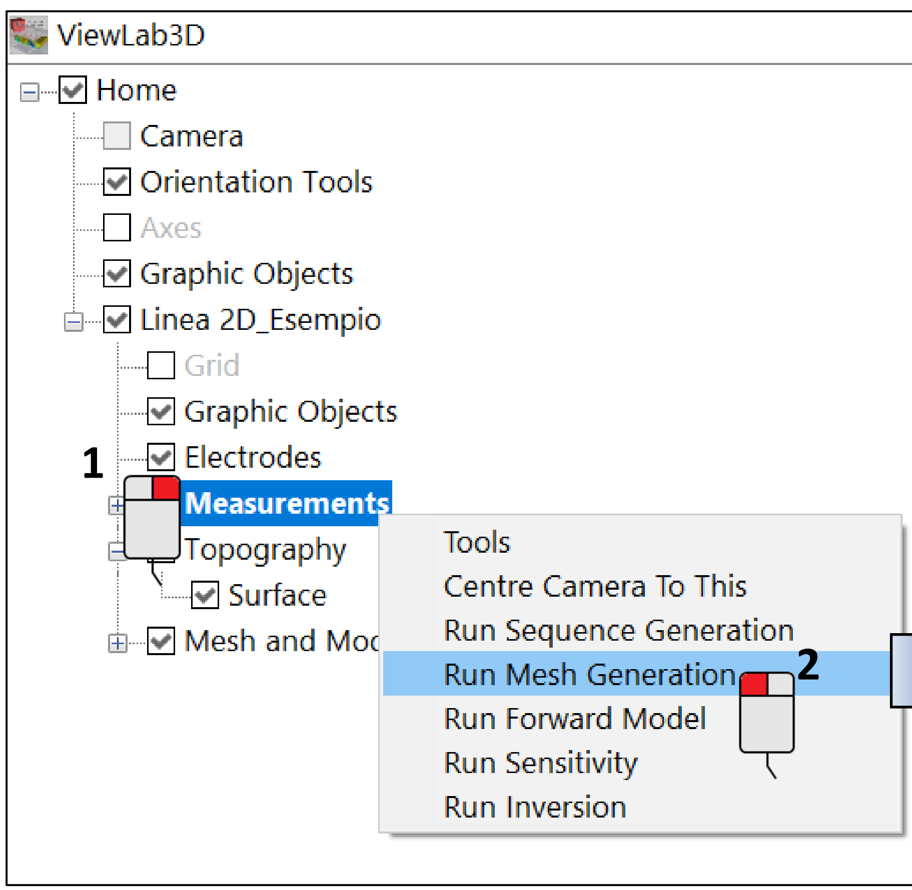
GEOstudi Astier

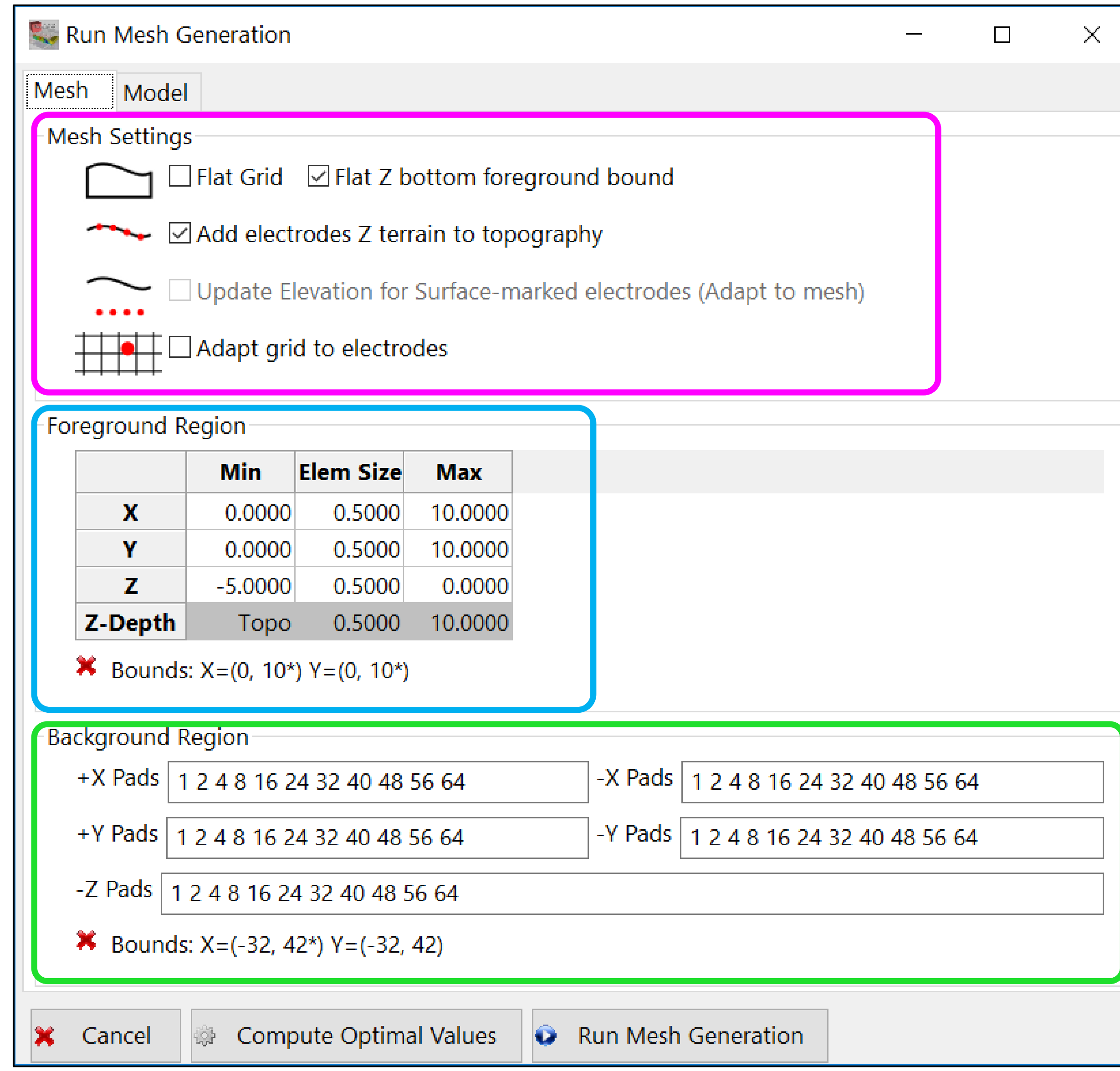
STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup

MESH → discretization of the subsurface in cells that define the domain under investigation and the space around it.

Filtered the data, before proceeding with the inversion it is necessary to discretize the investigated volume in cells.





Mesh Setting

Setting limits and size of 'Foreground' area

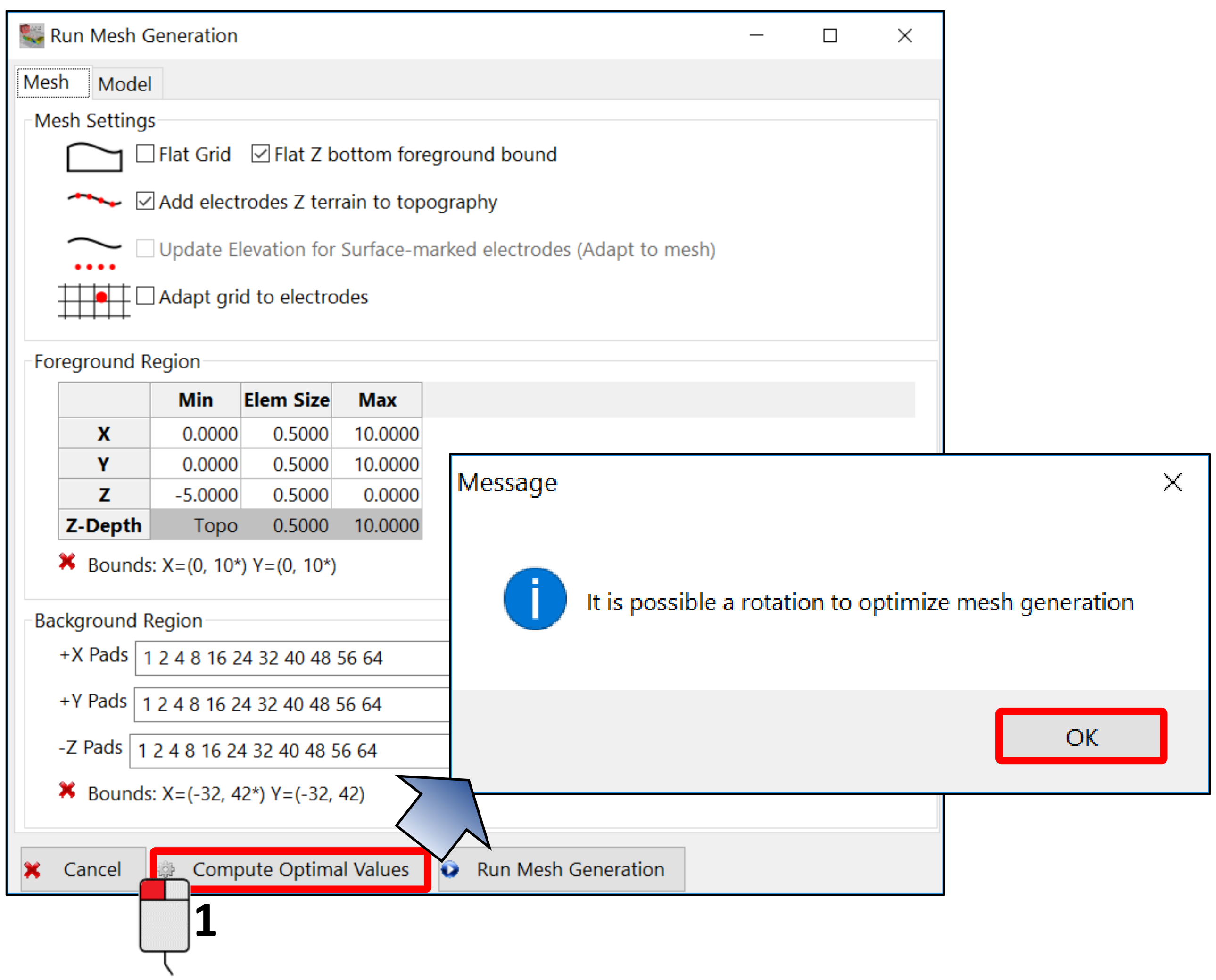
Setting size and limits of 'Background' area

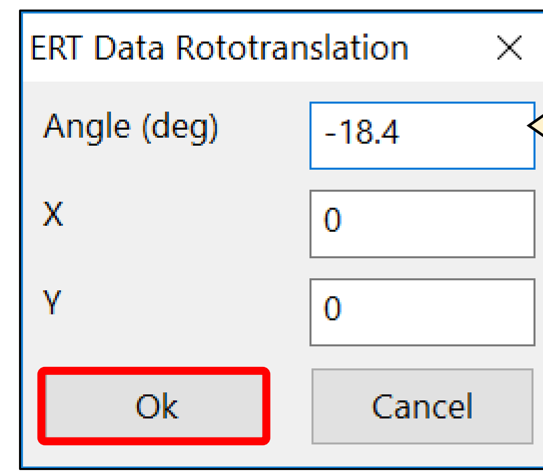
STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup_Automatic Configuration

By clicking *Compute Optimal Value*, ERTlLab *Studio* automatically calculates the optimal parameters for the creation of the mesh.

- If the shape of the investigated volume does not follow the main axes (X and Y), a System **Rotation** is suggested, to optimize the creation of the Mesh.





Rotation value (in degrees) automatically calculated by the system

At the end of processing it is possible to perform the ANTIROTATION (angle value with inverted sign, in this case +18.4) to return the system to the original coordinates.

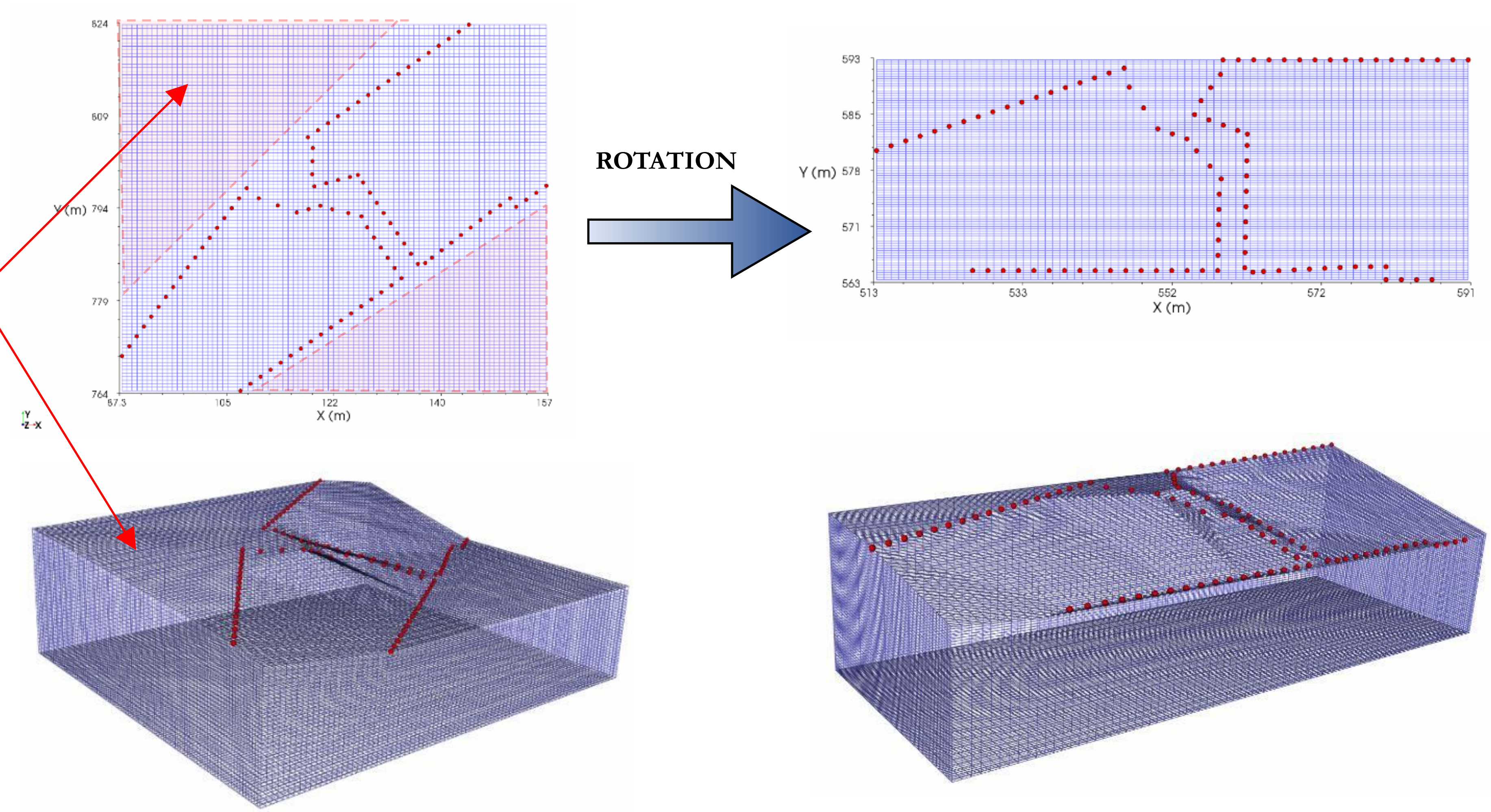
STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup_Automatic Configuration

Example

Area with cells where no measure were recorded. It causes a slowing down of the inversion process and data management.

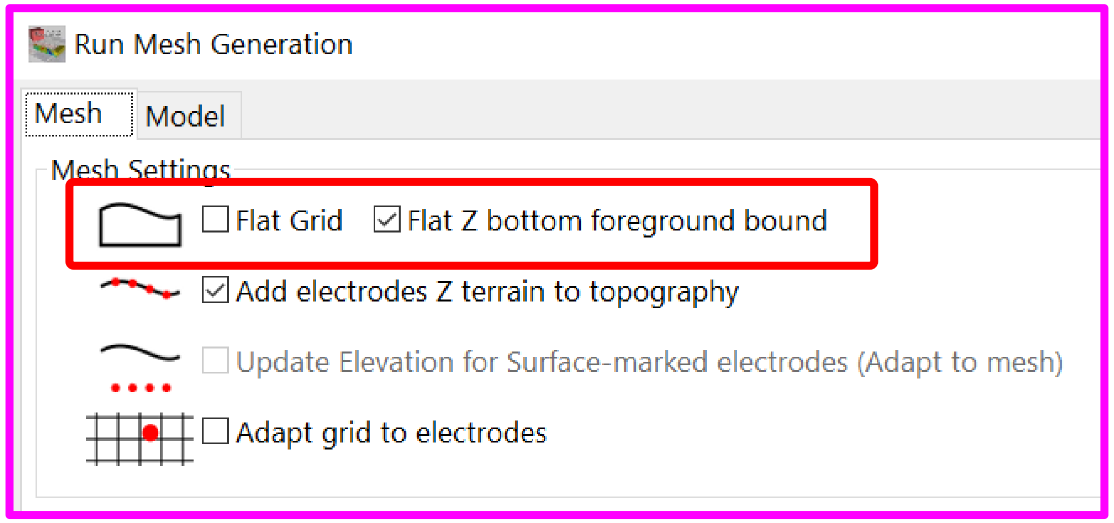
NOT optimized Mesh ***Optimized mesh***



If the automatic configuration does not meet expectations, it is possible to manually set the properties, as it shown in the following pages.

STEP 4: MESH AND MODEL SETUP

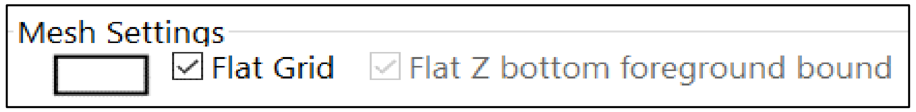
4.1 Mesh Setup_Customized Configuration



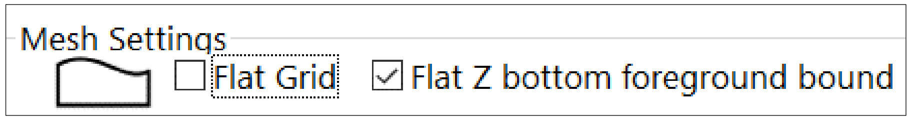
I. Select the **role of the Topography** in the Mesh generation

It is possible to make:

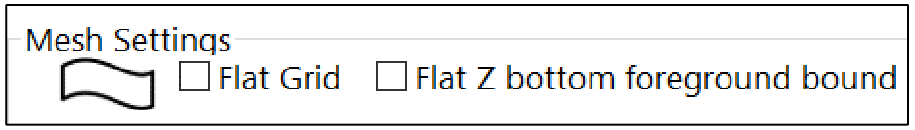
- A Mesh with flat top and bottom (**CASE A**)

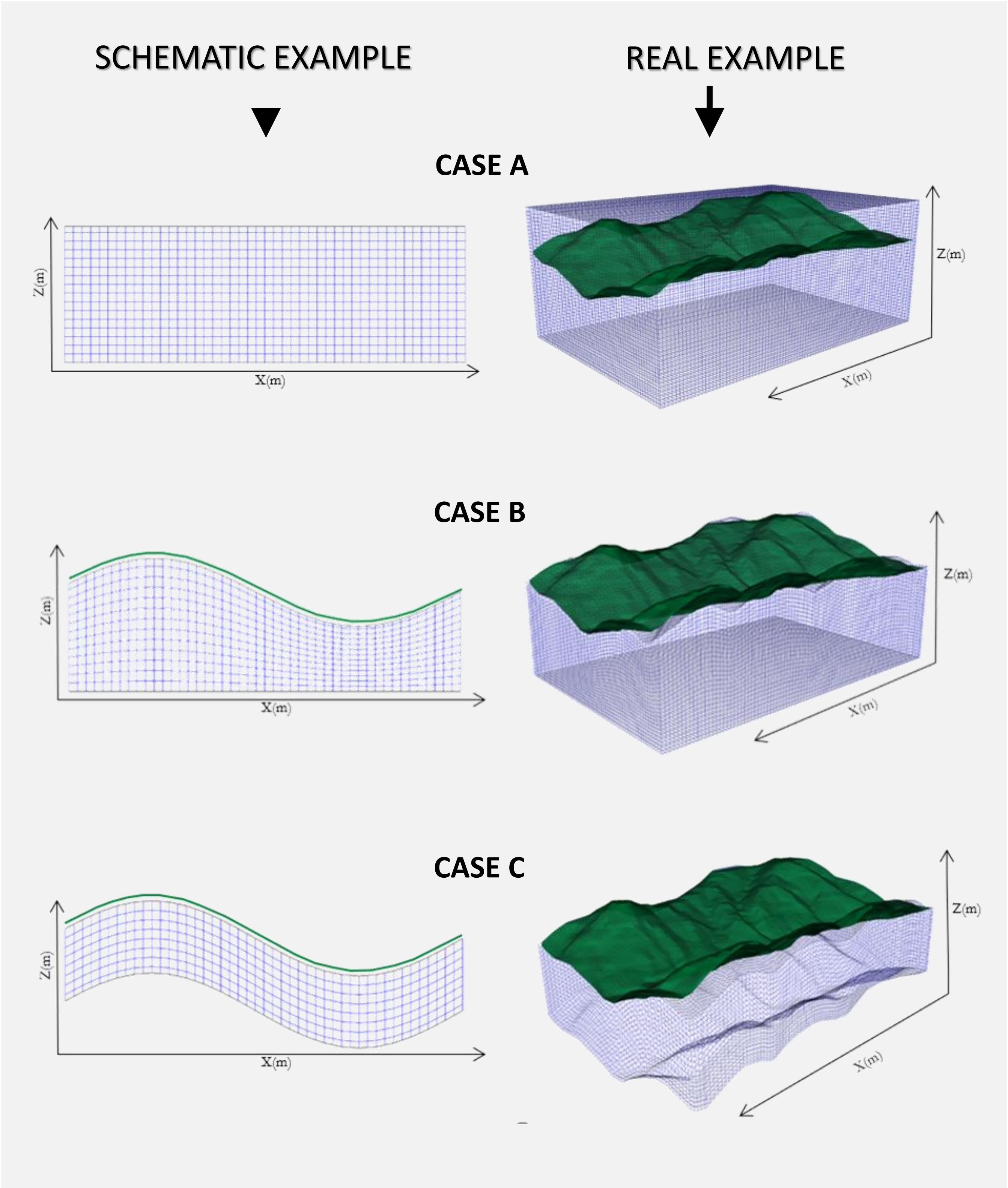


- A Mesh with a surface that follows the topography and a flat bottom (**CASE B**)



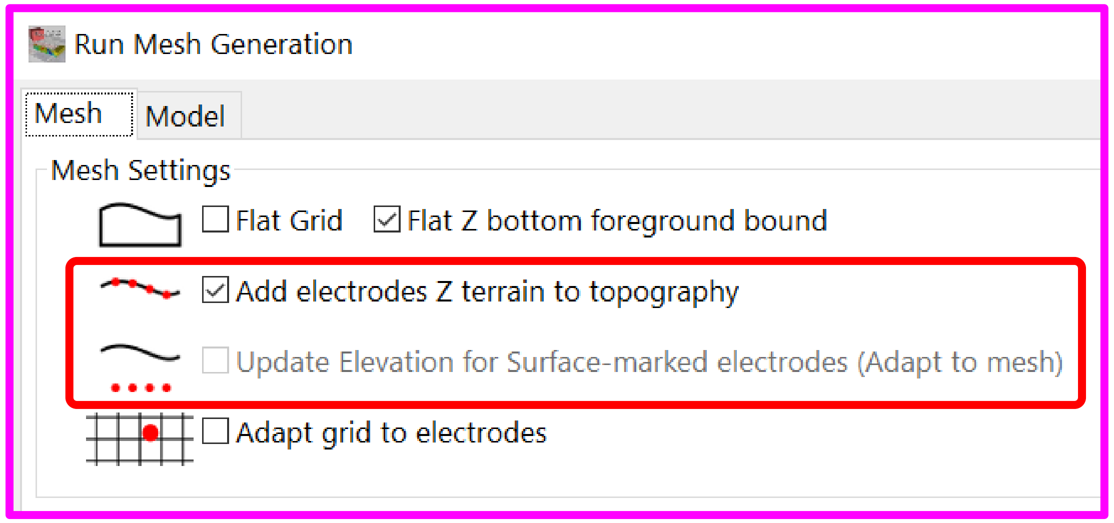
- A Mesh where both the surface and the bottom follow the topography (**CASE C**)

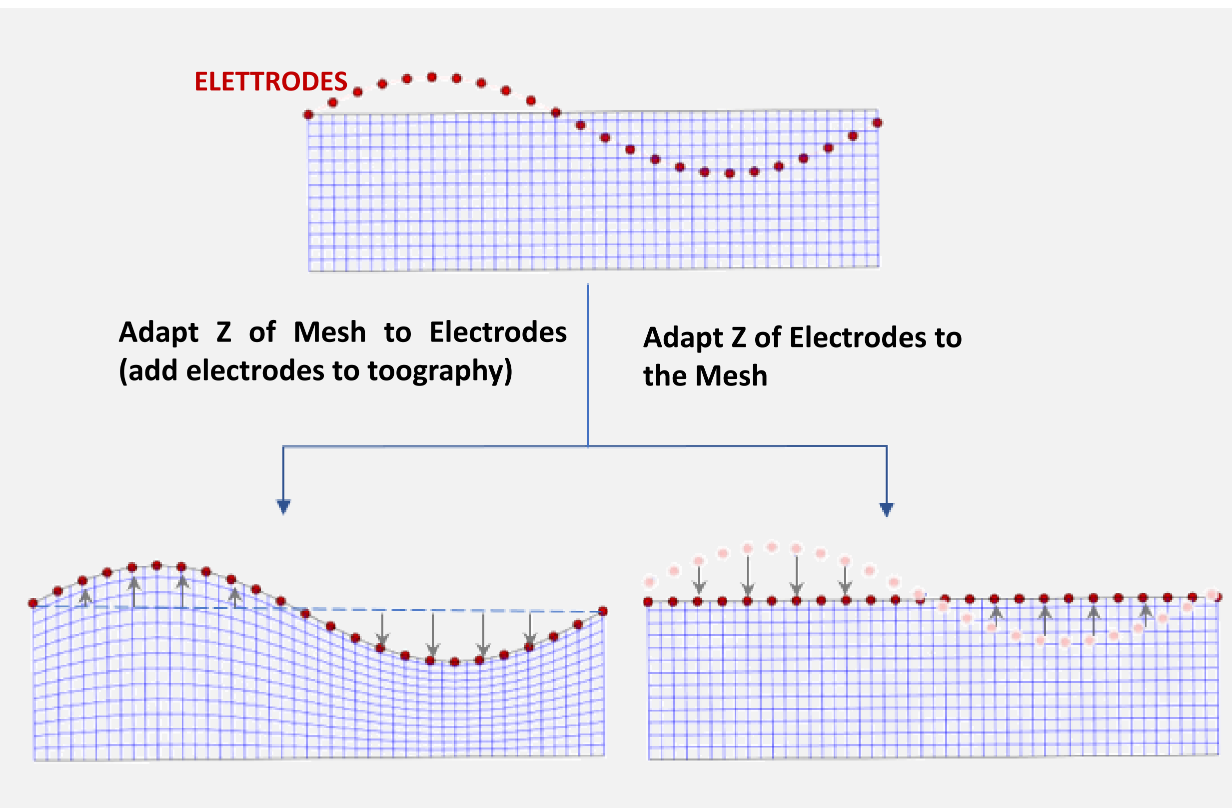




STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup_Customized Configuration





Schematic example of Mesh reconstruction based only on topographical electrode information

II. Define the **role of the Z-coordinate** in the Mesh generation.

- **IF** the Mesh has topographic information, the Z-coordinates of one or more electrodes may not be consistent with the topography file; in this case the electrodes appears suspended over the ground or buried.
  - It is necessary to adapt the Z-Coordinate of the Electrodes to the Mesh or, on the contrary, the Mesh Coordinates to the Electrodes.
  - In most cases, the Topography Z information is more accurate than the Z of the electrodes, so it is convenient to adapt the Z electrodes to the Mesh:

    ☐ Add electrodes Z terrain to topography

    ☑ Update Elevation for Surface-marked electrodes (Adapt to mesh)

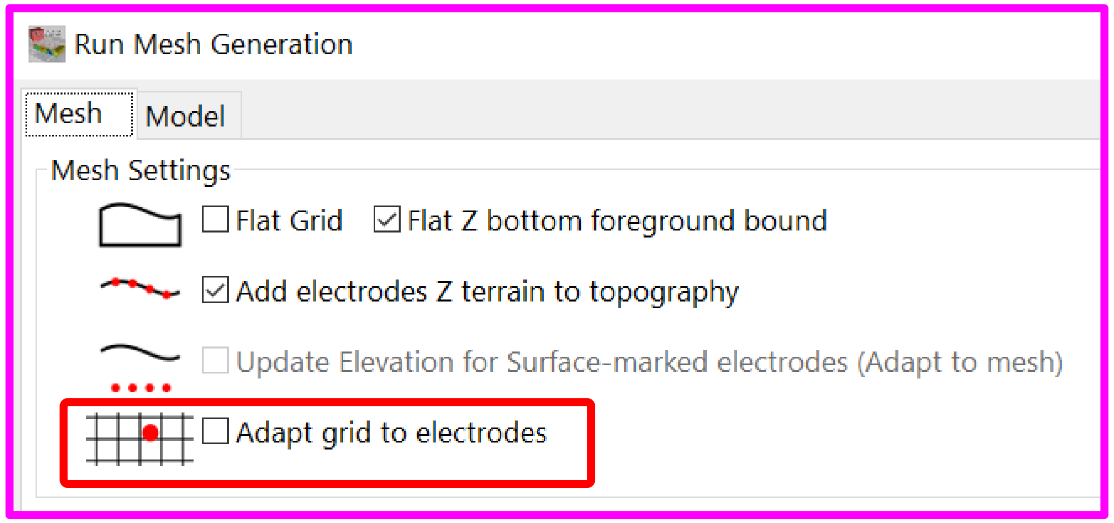
- **IF** the Mesh does NOT contain topographical information or the Z coordinates of the electrodes are more consistent (for example, if there is not a DEM file - Digital Elevation Model - but just few topographical scattered points):
  - **Adapt the Z of the mesh to the topography:**

    ☑ Add electrodes Z terrain to topography

    ☐ Update Elevation for Surface-marked electrodes (Adapt to mesh)

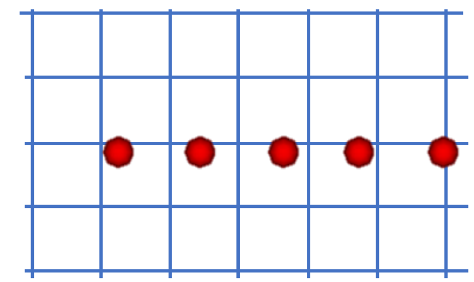
STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup_Customized Configuration



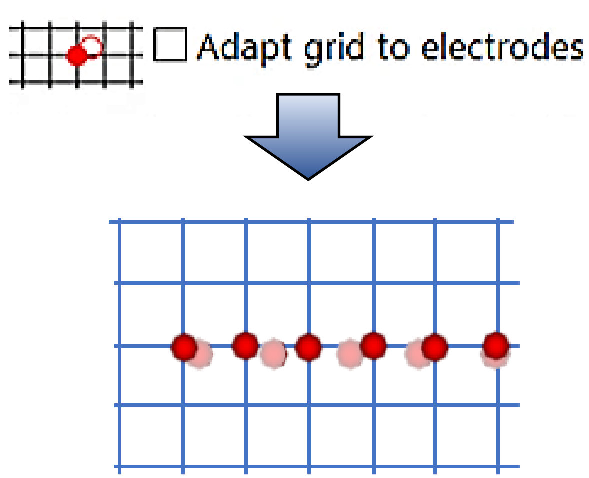
III. Define the **role of the X and Y coordinates of the electrodes** in Mesh generation.

It is possible that the position of one or more electrodes does not match any node of the Mesh:

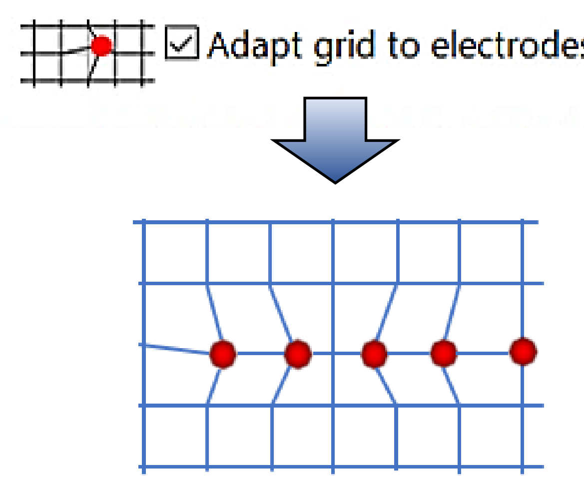


In this case, it is possible:

- MOVE THE ELECTRODES TO THE NEAREST MESH NODE



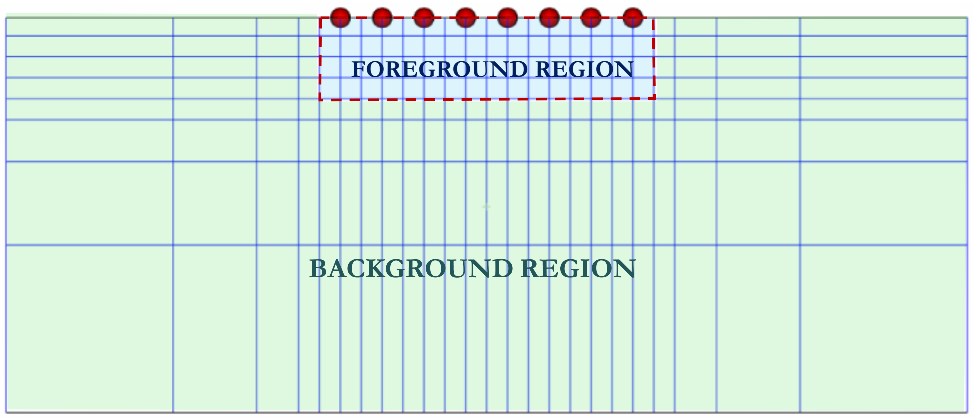
- DEFORM THE MESH SO THAT EACH ELECTRODE MATCHES A MESH NODE



STEP 4: MESH AND MODEL SETUP

4.1 Mesh Setup_Customized Configuration

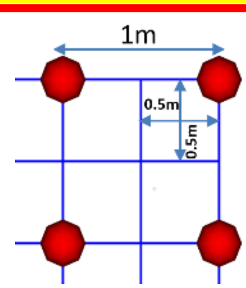
V. Definire i limiti del Foreground Region e del Background Region



FOREGROUND REGION → Portion of the mesh that includes the investigated area, defined by the geometry of the electrodes on the ground (volume actually investigated).

BACKGROUND REGION → Theoretically infinite area, necessary to define boundary conditions (edge effects).

X and Y minimum and maximum values are determined by the coordinate of the electrodes

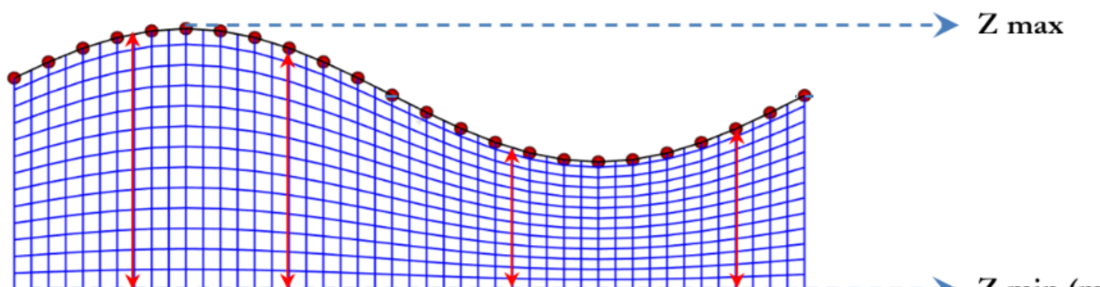


The **ideal cell size** corresponds to half the electrodic distance (so 0.5m in case of electrodes spaced 1m apart). It is possible to choose other values, but it is recommended to use values corresponding to multiples and sub-multiples of the electrodic distance.

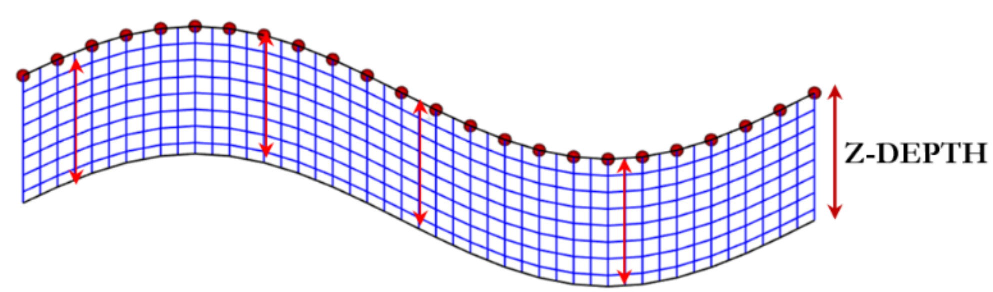
Foreground Region

	Min	Elem Size	Max
X	0.0000	0.5000	10.0000
Y	0.0000	0.5000	10.0000
Z	-5.0000	0.5000	0.0000
Z-Depth	Topo	0.5000	10.0000

IF the bottom of the Mesh is **flat →** Z Depth (thickness) is NOT editable, because the thickness is not constant; define a minimum and maximum Z value



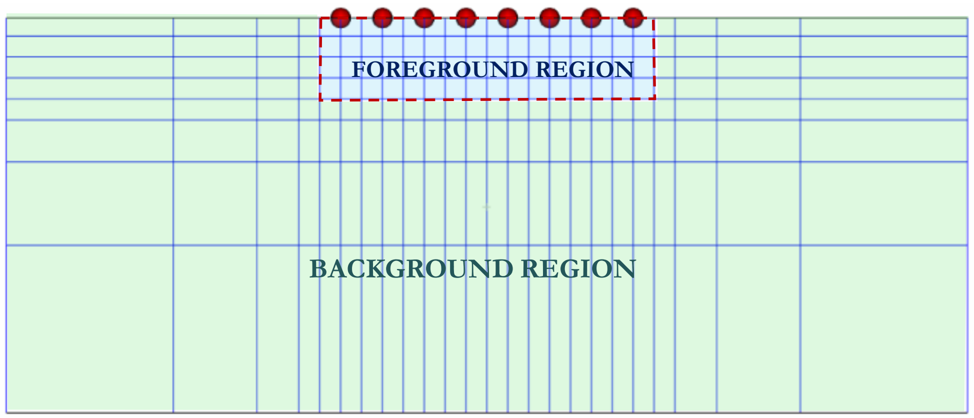
IF the bottom of the Mesh follows the **topography →** the thickness is constant, so it is sufficent to set the **Z-Depth** (and the Z row becomes NOT editable)

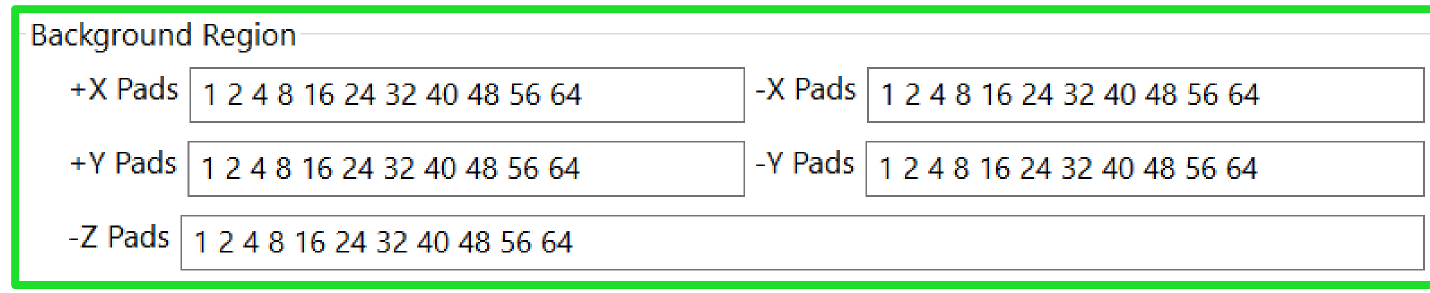


STEP 4: MESH AND MODEL SETUP

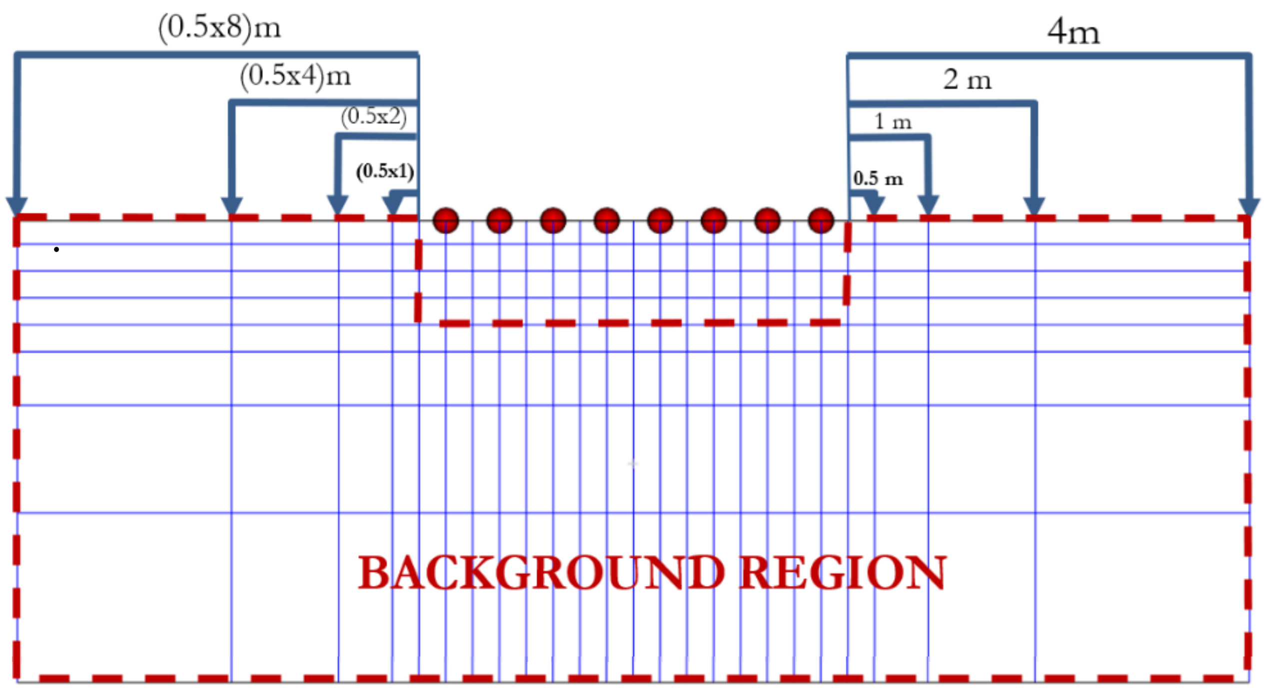
4.1 Mesh Setup_Customized Configuration

V. Define the limits of the **Foreground and theBackground Region**





The dimension of the **Background Region** is defined by pads: each number manages the location of one Background node. The number *n* indicates *n* times the size of the Foreground cell.



Example

If the cell size in X is 0,5 m:

Pad 1 is equivalent to a background cell of 0,5 m (1x0,5);

Pad 2 to a 1m background cell (2x0,5);

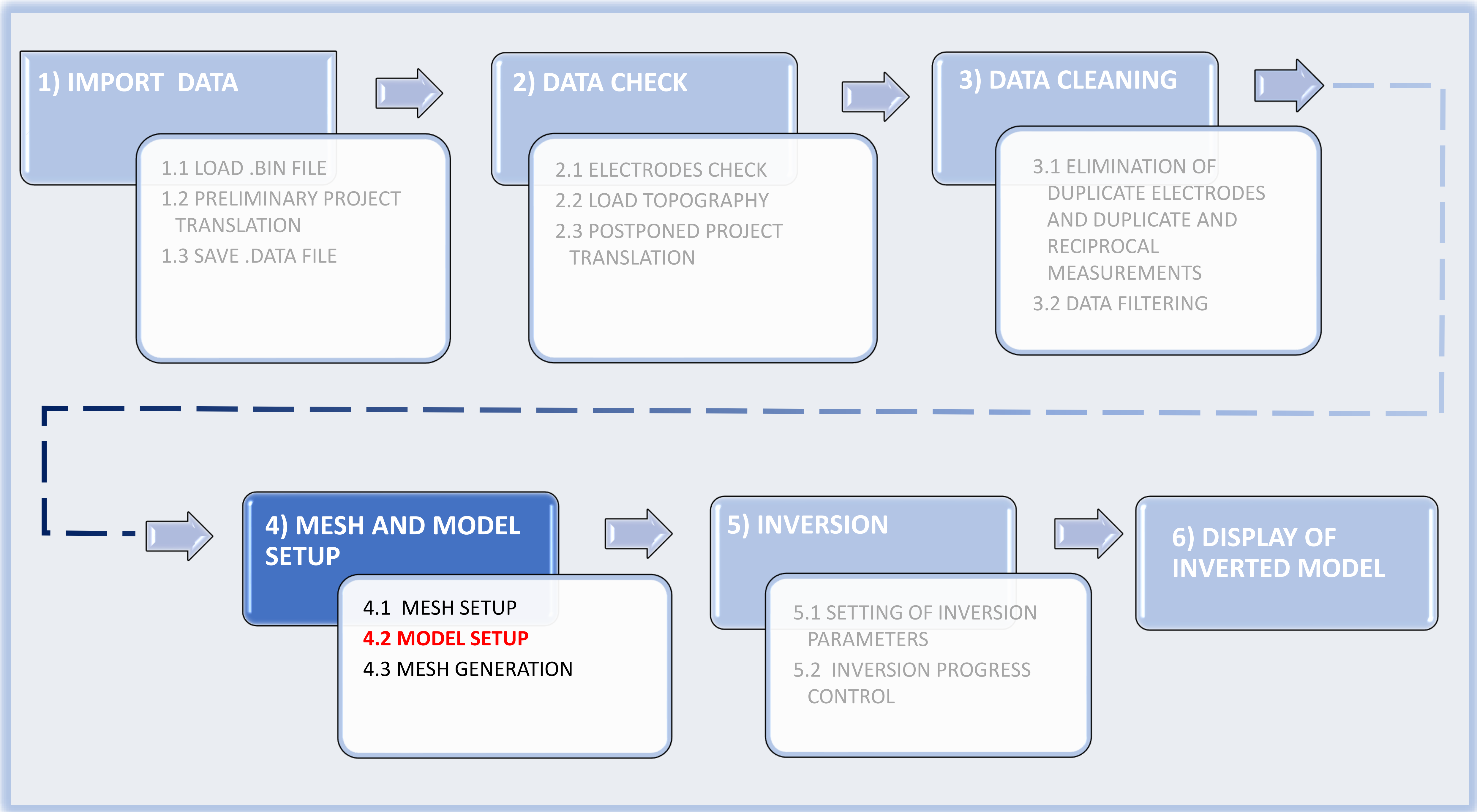
Pad 4 to a 2m background cell (4x0.5);

Pad 8 to a 4m background cell (8x0,5).

If it is changed the number of pads in the Background region compared to the automatically calculated pads, make sure that the REMOTE POLE is included in the Mesh.

ERTLab *Studio*

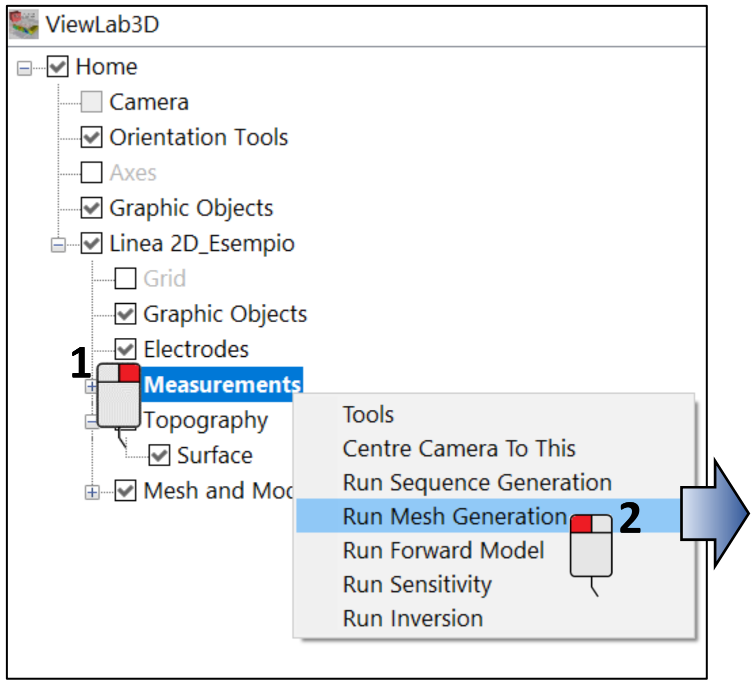
WORKFLOW CHART FOR ERT DATA PROCESSING

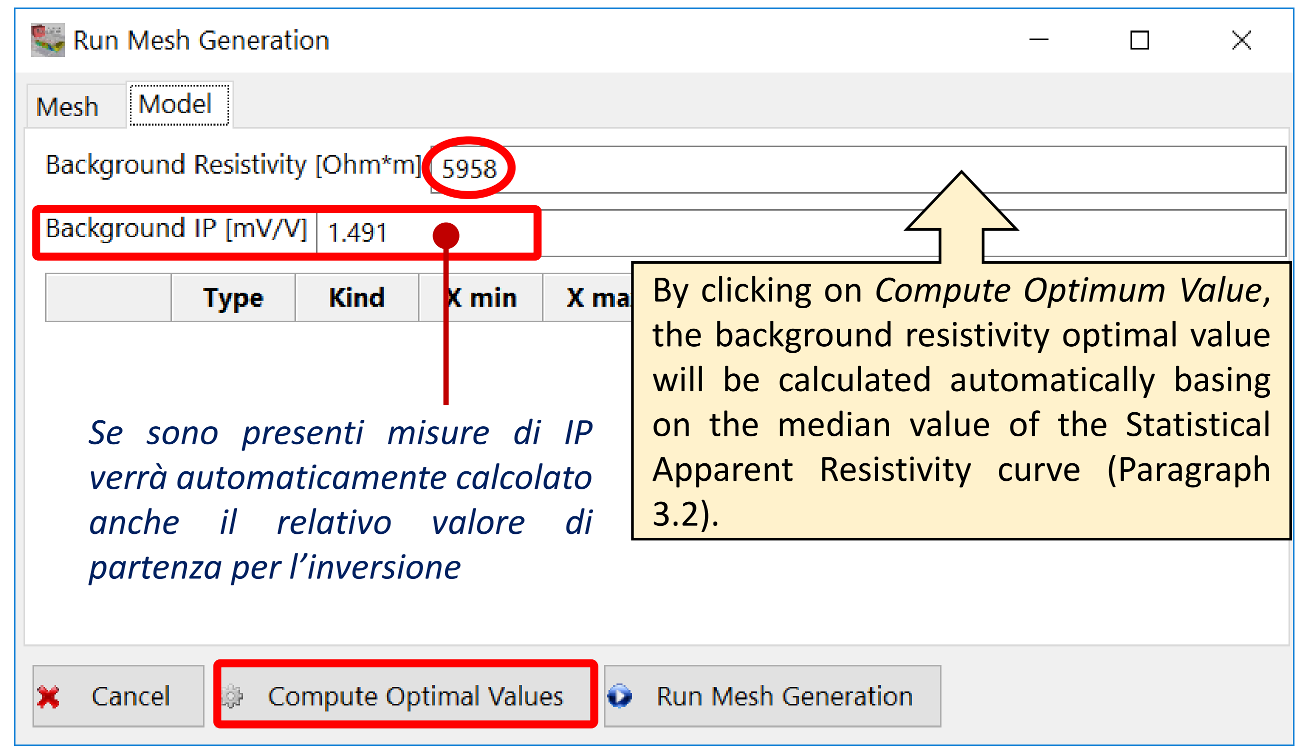


STEP 4: MESH AND MODEL SETUP

4.2 Model Setup

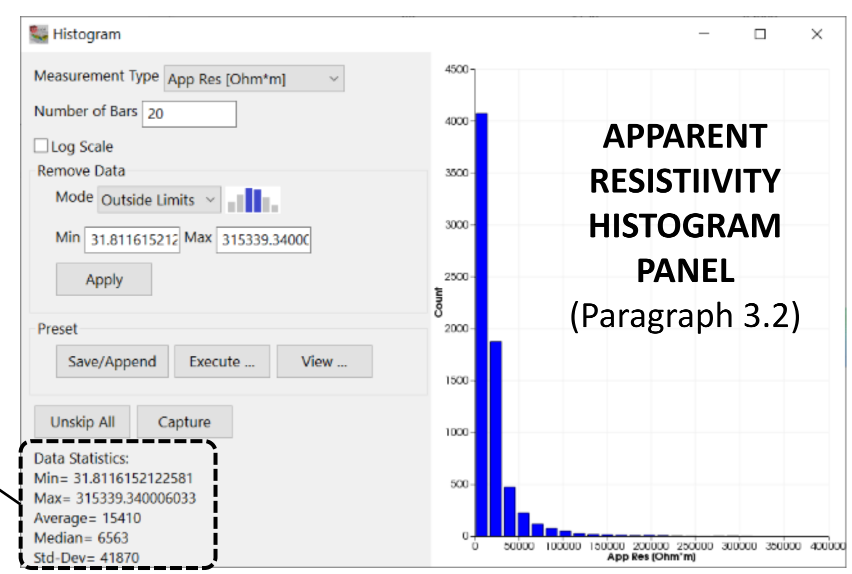
After setting the Mesh, it is necessary to set the Resistivity value of the model from which the inversion process will start.





It is possible to enter the desired value in the proper box, considering the average and median values of the Apparent Resistivity of the filtered dataset.

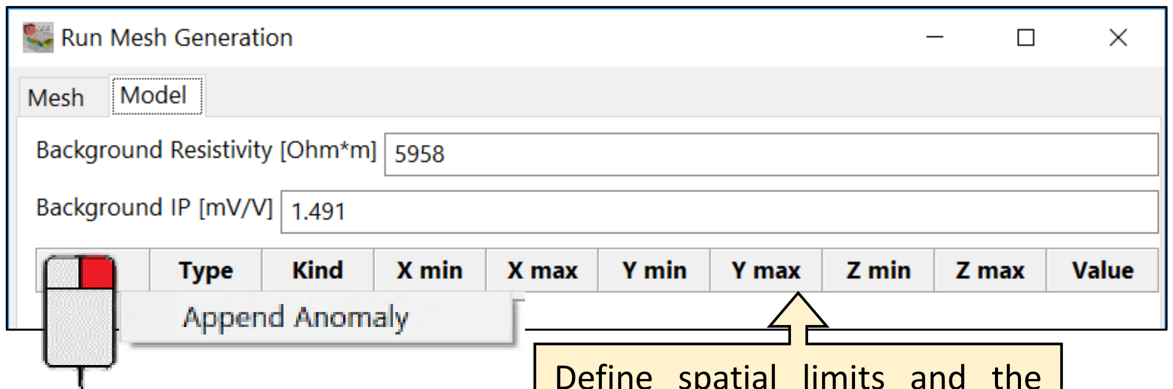
Data Statistics:
Min= 31.8116152122581
Max= 315339.340006033
Average= 15410
Median= 6563
Std-Dev= 41870



STEP 4: MESH AND MODEL SETUP

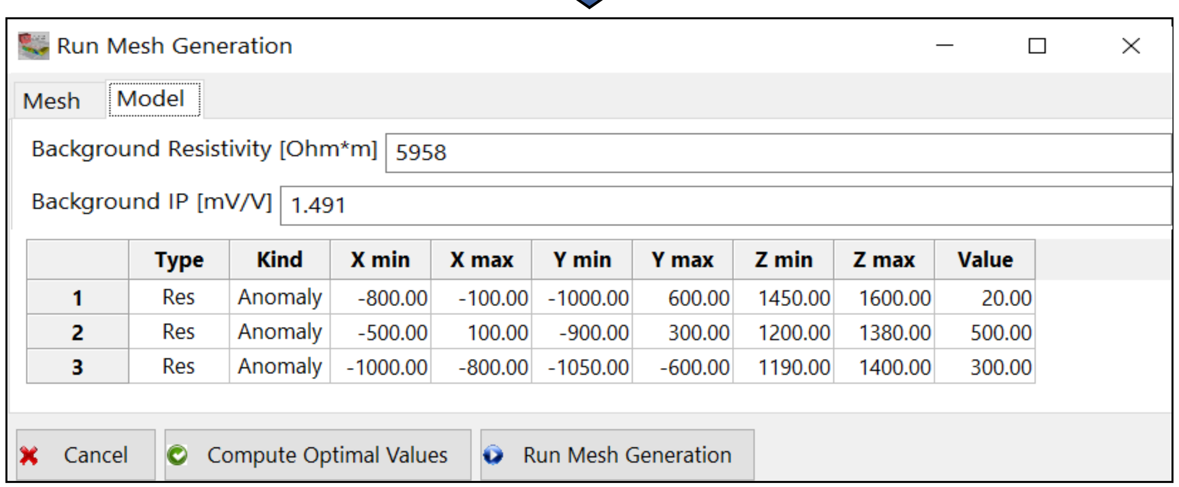
4.2 Model Setup

It is also possible to start from a non-homogeneous model by inserting one or more anomalies, or a known stratigraphy:



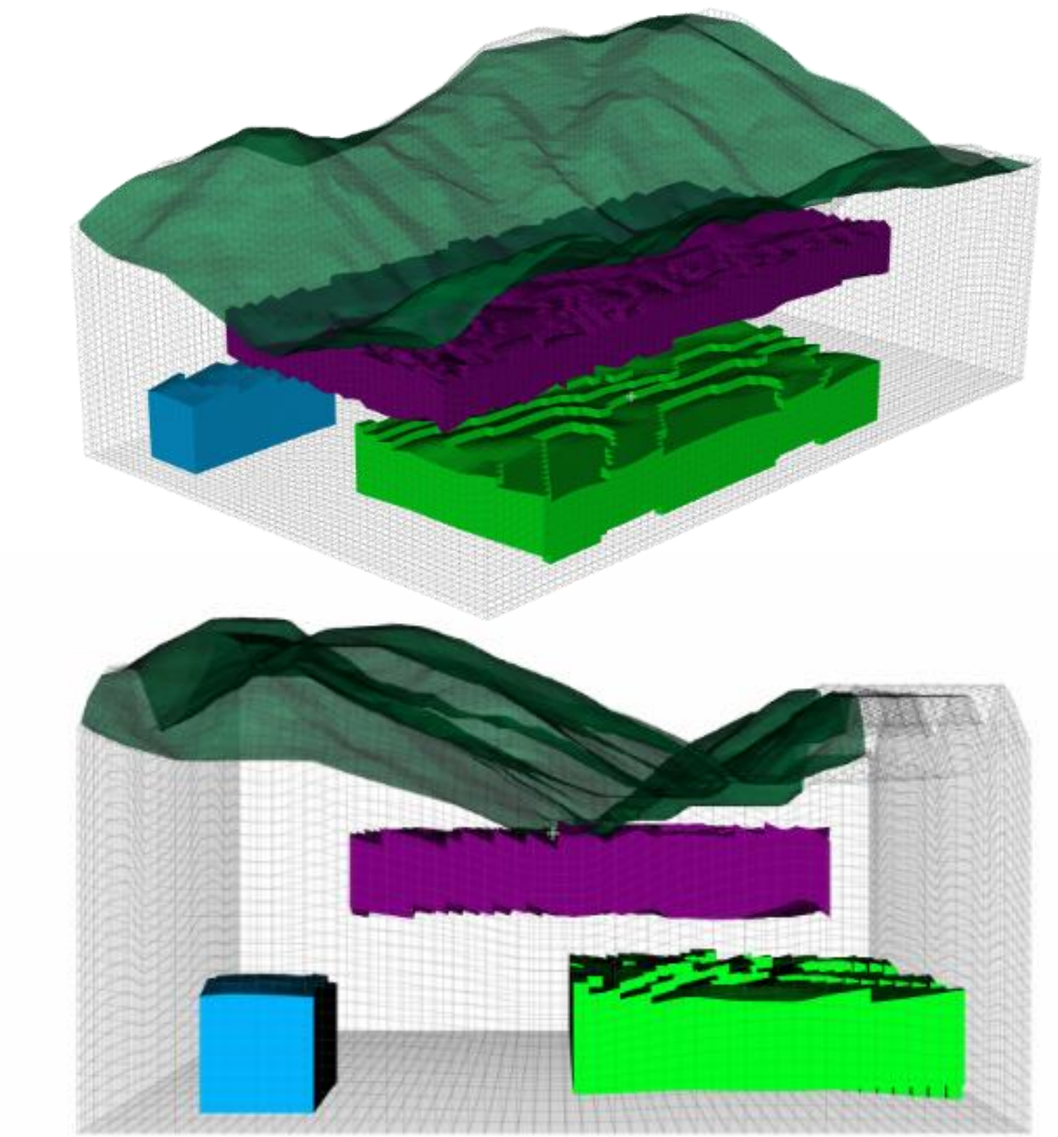
Define spatial limits and the Resistivity value of the anomaly

Repeat for each anomaly to add



	Type	Kind	X min	X max	Y min	Y max	Z min	Z max	Value
1	Res	Anomaly	-800.00	-100.00	-1000.00	600.00	1450.00	1600.00	20.00
2	Res	Anomaly	-500.00	100.00	-900.00	300.00	1200.00	1380.00	500.00
3	Res	Anomaly	-1000.00	-800.00	-1050.00	-600.00	1190.00	1400.00	300.00

***Example** of Mesh with 3 anomalies inserted, from two points of view.*



ERTLab *Studio*

WORKFLOW CHART FOR ERT DATA PROCESSING

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2.3 POSTPONED PROJECT TRANSLATION

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3.2 DATA FILTERING

4) MESH AND MODEL SETUP

4.1 MESH SETUP
4.2 MODEL SETUP
4.3 MESH GENERATION

5) INVERSION

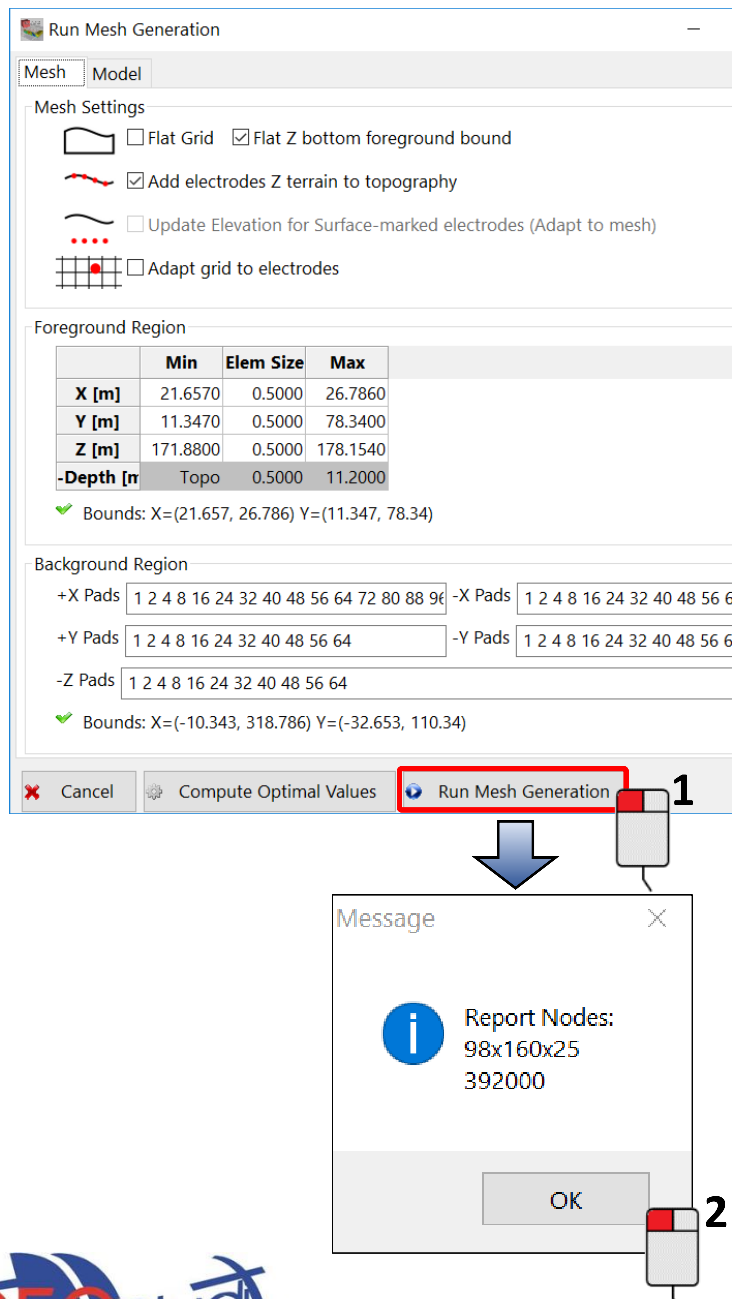
5.1 SETTING OF INVERSION PARAMETERS
5.2 INVERSION PROGRESS CONTROL

6) DISPLAY OF INVERTED MODEL

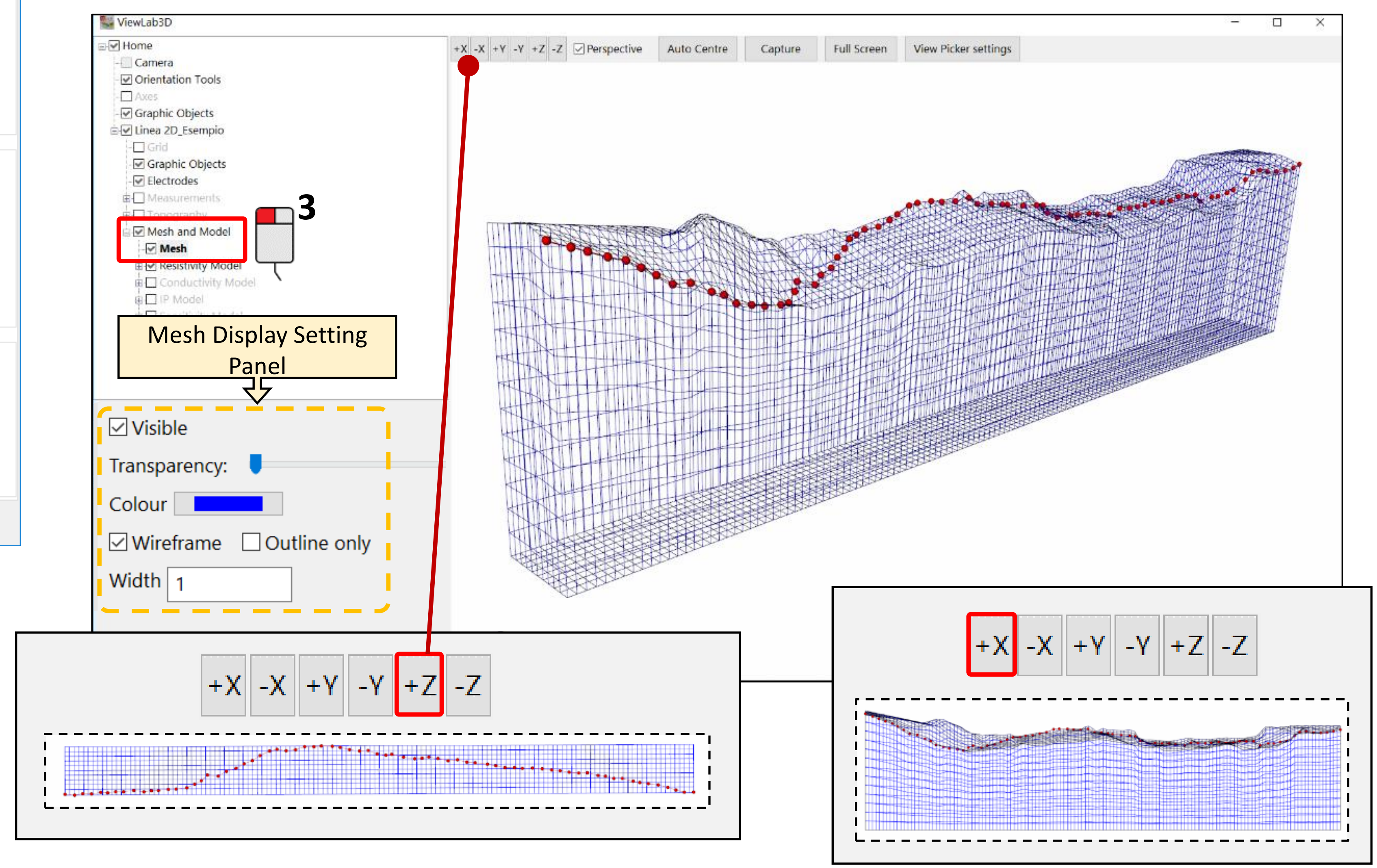
STEP 4: MESH AND MODEL SETUP

4.3 Mesh Generation

After setting the *Mesh* and the *Model,* **generate the Mesh** using the *Run Mesh Generation* button. Manage the display mode using the *Mesh* and *Model* node.



***Examples** of Mesh from different points of view*



ERTLab *Studio*

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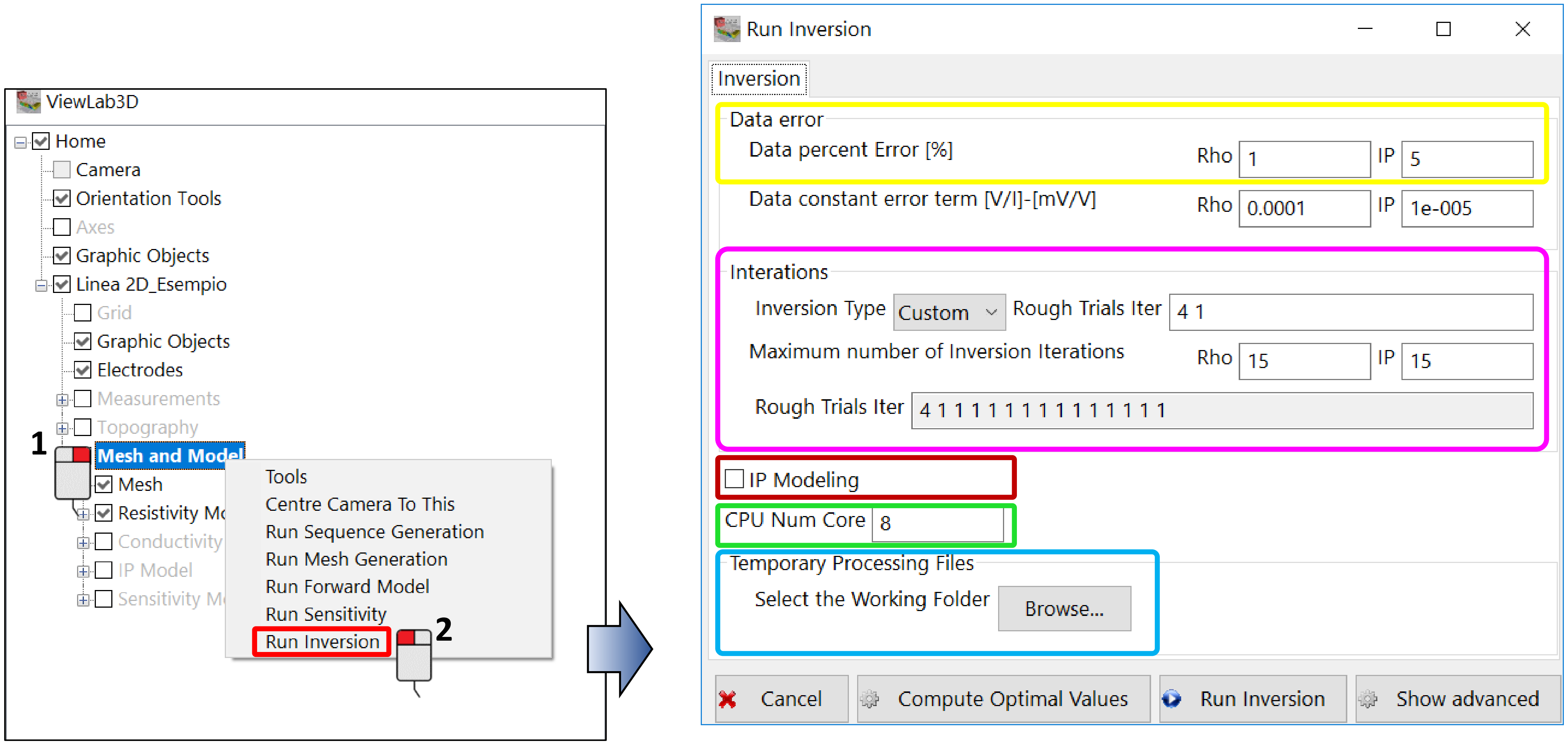
- **5.1 SETTING OF INVERSION PARAMETERS**
- 5.2 INVERSION PROGRESS CONTROL

6) DISPLAY OF INVERTED MODEL

STEP 5: INVERSION

5.1 Setting of inversion parameters

Generated the Mesh, the last step is to set the parameters of data inversion. Clicking *Compute Optimal Value*, ERTLab *Studio* automatically calculates the optimal parameters for the inversion.



Noise setting

Inversion-type setting

Elaboration of Induced Polarization (IP) Data

Setting of PC resources to dedicate to the inversion

Setting of the folder for saving Temporary Files

STEP 5: INVERSION

5.1 Setting of inversion parameters

If the automatic configuration does not meet expectations, it is possible to manually set the various properties.

I. Setting *Iterations*

IN THEORY

GOOD MODEL (THAT SATISFY THE PROBLEM OF INVERSION) → MODEL THAT REPRODUCE EXACTLY THE FIELD DATA. → SO → AIM OF INVERSION: **Field data – Modeled data ≈ 0**

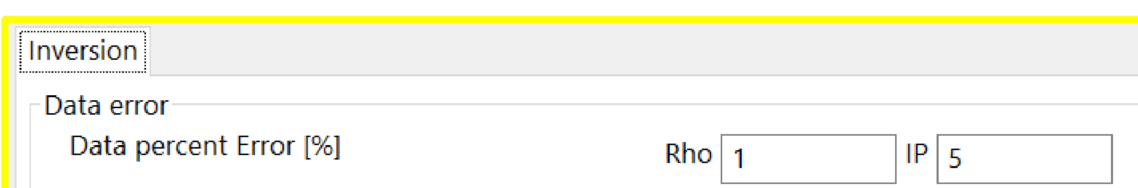
BUT

FIELD DATA → are affected by errors (noise)

SO

ACTUALLY

GOOD MODEL (THAT SATISFY THE PROBLEM OF INVERSION) → MODEL THAT REPRODUCE THE FIELD DATA WITH A CERTAIN ERROR → SO → AIM OF INVERSION: **Modeled data = Field data + *noise***



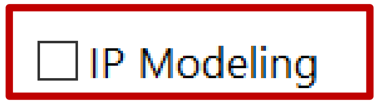
This panel allows to set the Rho and IP error in terms of percentage error; higher is the noise of the data, higher is the Data Percent Error to set (indicatively, 1 for very clean data, 3-5 for data with medium signal/noise ratio, 10 or more for very noisy data).

STEP 5: INVERSION

5.1 Setting of inversion parameters

II. Inversion *IP* data

ERTLab *Studio* can simultaneously process Electrical Resistivity (Rho) and Induced Polarization (IP) data. To include the **IP** data in the inversion, check the proper box.



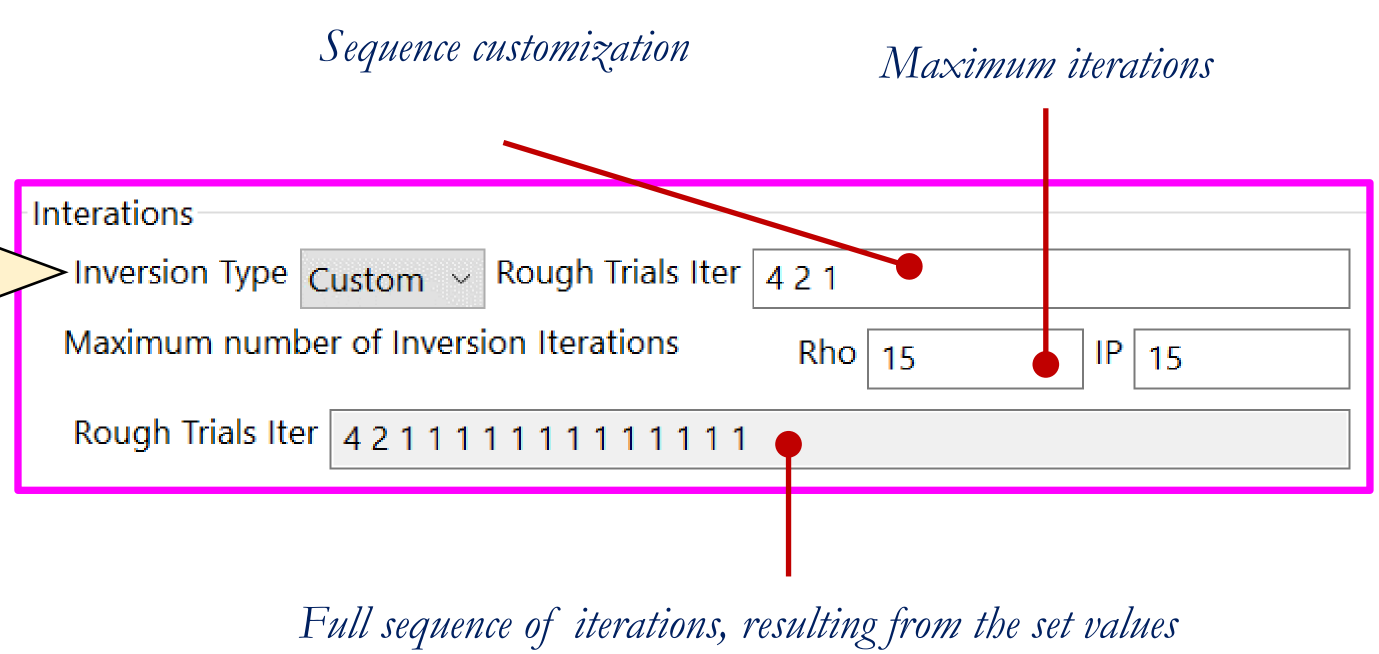
II. *Iteration* setting

Inversion process proceeds by 'trials' to determine optimal roughness parameters to use on each iteration. This operation can take a long time, so it is possible to choose the number of trials to run on each iteration.

SIMPLE (4 1): performs 4 trials on the 1st iteration and 1 trial from the 2nd iteration onwards.

COMPLETE (4): performs 4 trials on each iteration, from the first to the last.

CUSTOM: it allows to choose the number of trials on each iteration, writing the proper numbers in the dedicated box.



Example of *custom* sequence:

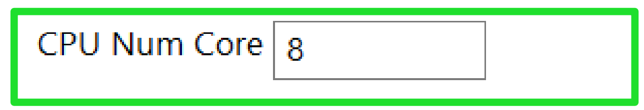
In this case, a maximum of 15 iterations are performed; in the first iteration, 4 trial are performed, in the second 2 and from the third to the fifteenth only 1.

STEP 5: INVERSION

5.1 Setting of inversion parameters

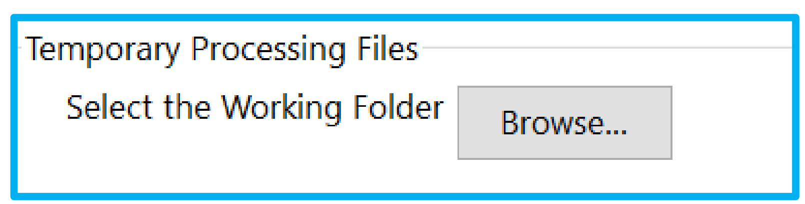
III. *Core* pc setting

The value depends on the hardware characteristics of the computer you are working on. As the threads used for inversion increase, the processing time decreases.



IV. Setting of the folder of *Temporary Files*

It lets to choose where to save the temporary files with the various intermediate steps of the inversion process.



For Advanced Functions (Boundary conditions, Robust Inversion, PCG iterative solver parameters, ...) refer to the User Guide.

ERTLab *Studio*

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- **5.2 INVERSION PROGRESS CONTROL**

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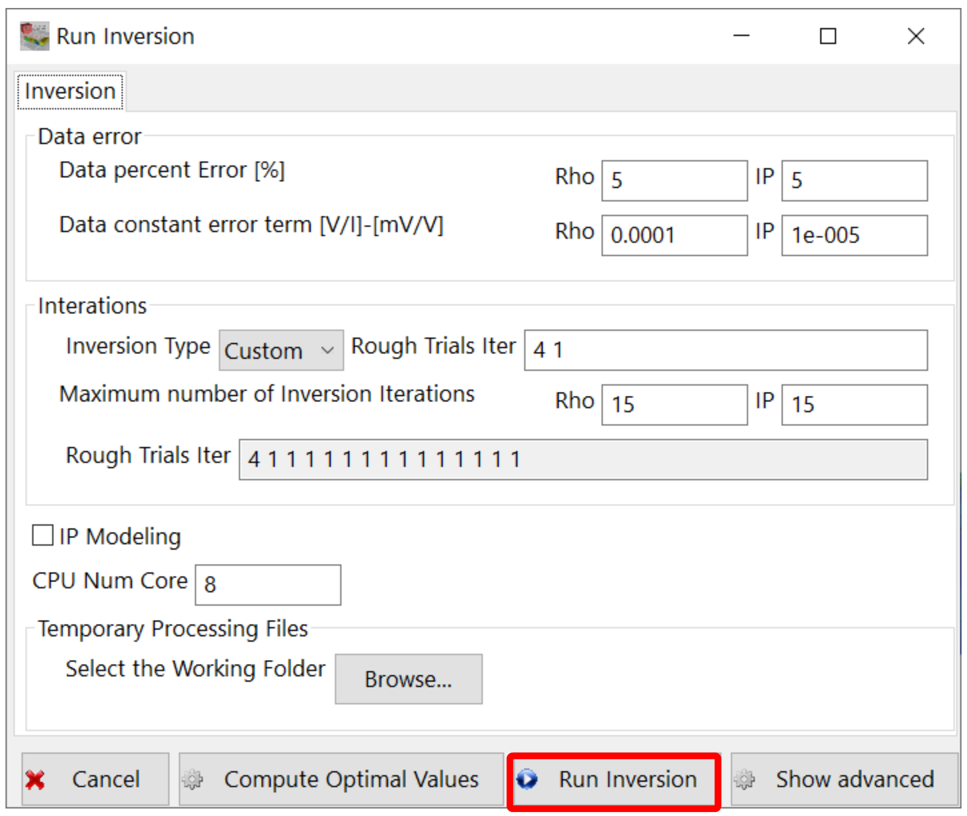
STEP 5: INVERSION

5.2 Inversion progress control

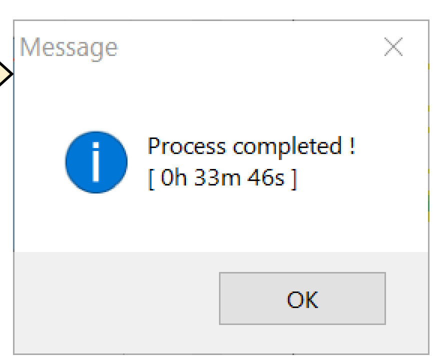
Click on **Run Inversion** to let the inversion starts; select the project folder where the inversion files will be automatically saved. A progress window of the processing will appear on the screen and it will be completed automatically as the elaboration proceeds.
When processing is end, a warning message will be displayed.

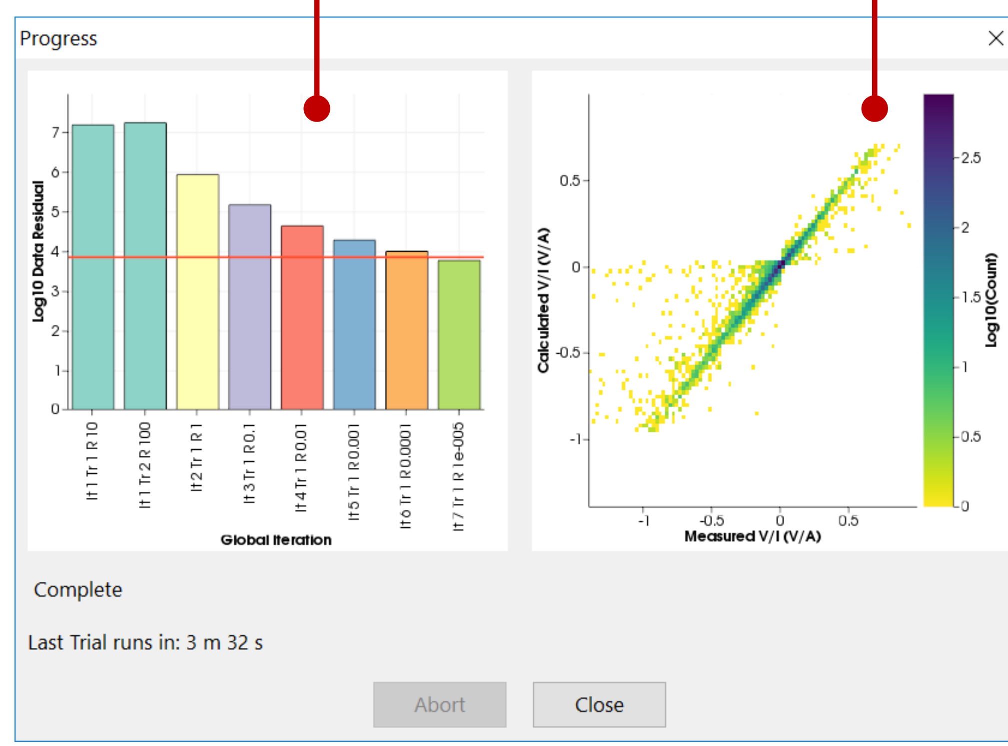


PROGRESS OF INVERSION
The bars represent the accuracy of the Inversion

Cross-plot between modeled data and filed data.

Message of **Inversione completed**, with processing time taken



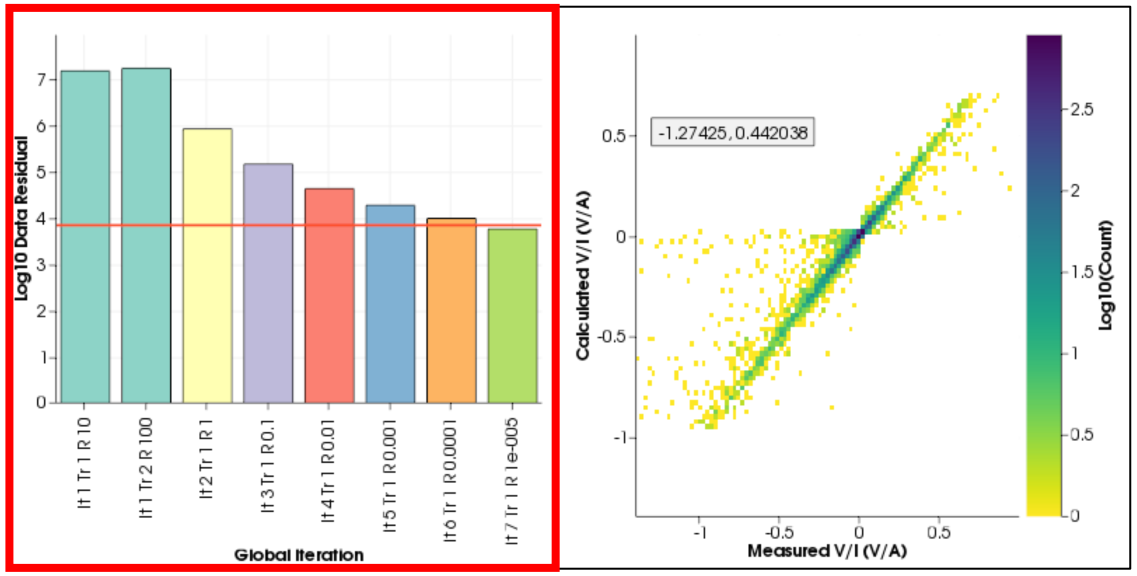


Inversion summary chart

STEP 5: INVERSION

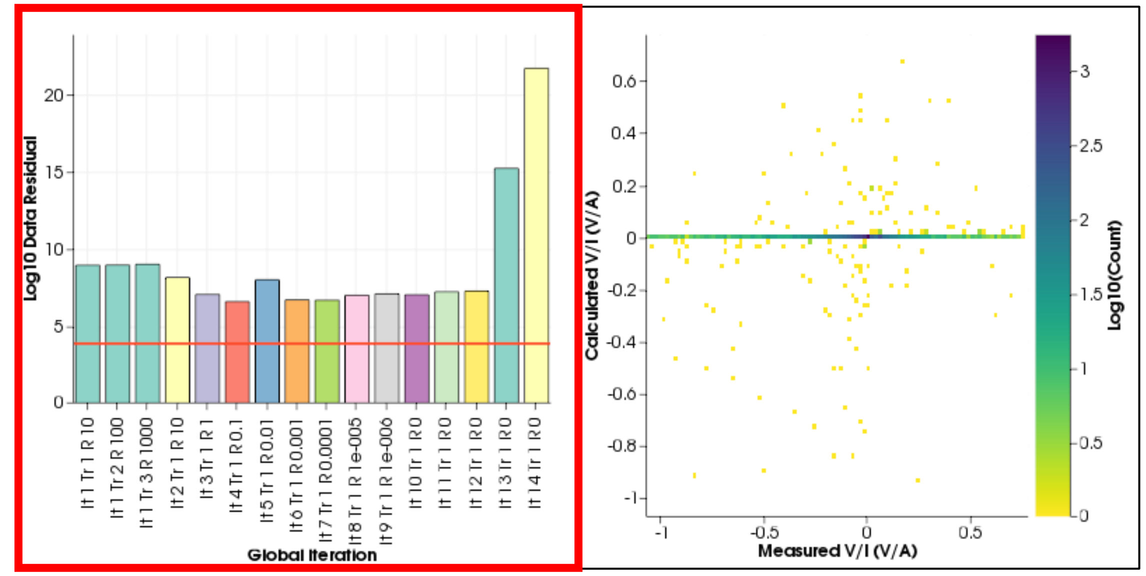
5.2 Inversion progress control

RELIABLE INVERSION



- Histograms decrease in height as iterations proceed (the residual decrease as the inversion proceeds);
- The last bar of the histogram corresponds in height to the red line (ideal inversion target = number of measurements to process).
- Low number (7) of iterations (easy to converge).

NOT RELIABLE INVERSION



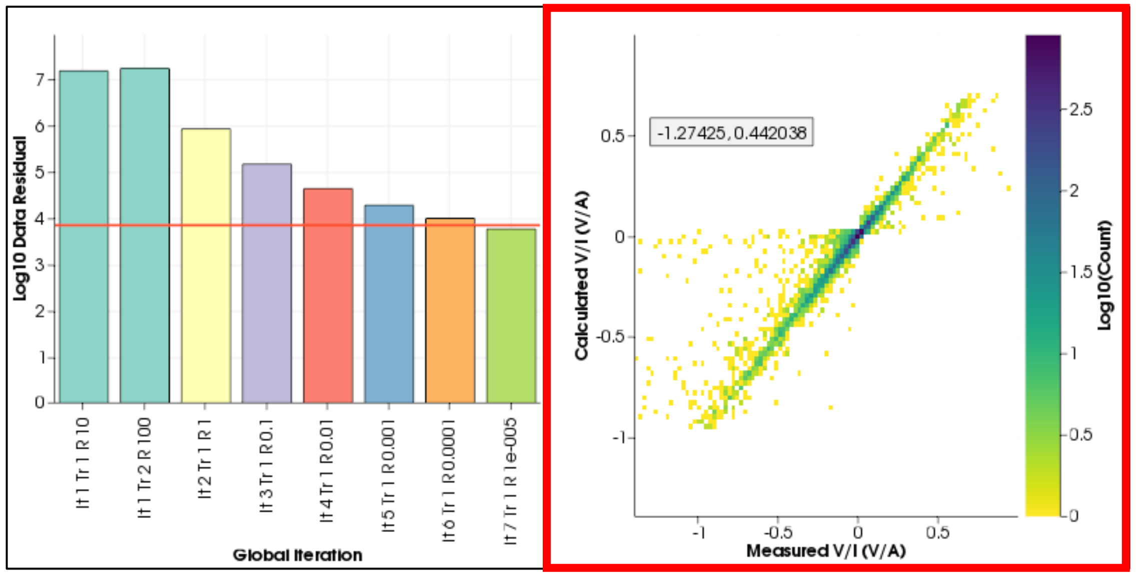
- The histograms remain at a constant height from iteration 6 to 12 (no progress at the proceed of inversion) and at the last 2 iterations they are opposite to the trend, reaching very high residual values.
- The last bar in the histogram does not match the red target line.
- High number of iterations (14 iterations), for difficulty in convergence.

The inversion summary chart is automatically saved in the project folder (chosen when the inversion was started) with the name ***RES Iter*** *n* ***Trial****n.*

STEP 5: INVERSION

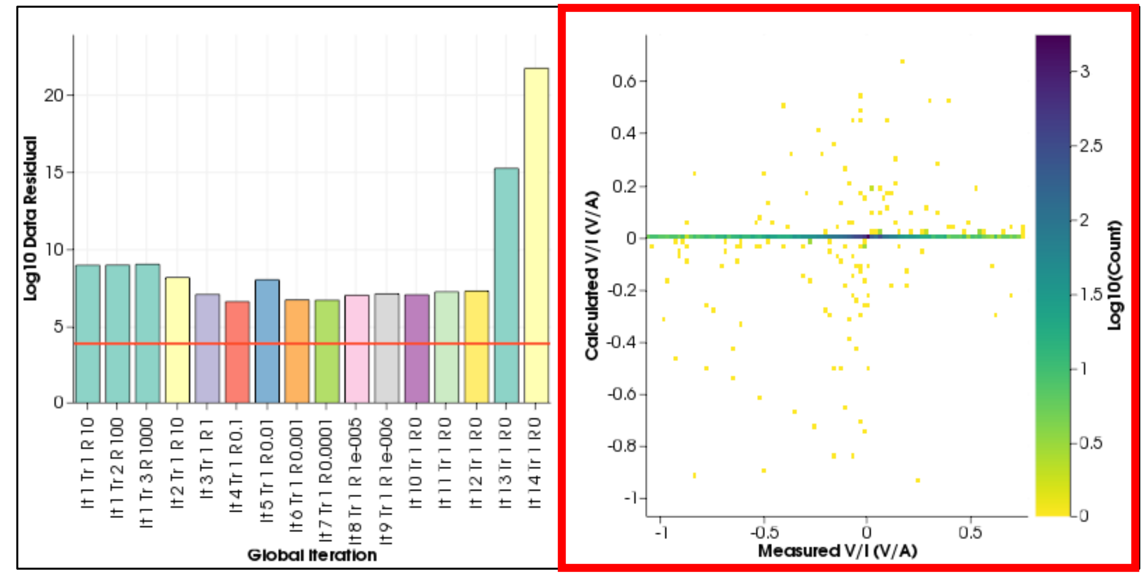
5.2 Inversion progress control

INVERSIONE ATTENDIBILE



- At the end of the inversion, the plot between field data and calculated data is near to 1:1 ratio, and data are distributed along the diagonal;
- Abnormal values (outliers, yellow dots, where the absolute difference between modeled data and measured data is high) are in the minority.

INVERSIONE *NON* ATTENDIBILE



- At the end of the inversion, the plot between field data and calculated data is far from the diagonal (in this case they are align along 0 of calculated V/I)
- Outliers (yellow dots, where the absolute difference between modeled data and measured data is high) are the majority of data and they are distributed almost evenly throughout the cross-plot.

CHECK AND EVENTUALLY FURTHER CLEAN FIELD DATA, EDIT THE NOISE AND/OR THE STARTING MODEL AND PROCEED AGAIN WITH INVERSION

ERTLab *Studio*

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6) DISPLAY OF INVERTED MODEL

STEP 6: DISPLAY OF INVERTED MODEL

At the end of the inversion processing, it is possible to visualize the result by activating the **Resistivity Model** node from the tree menu. It is possible to custom the way to represent data choosing between sections in each direction, volumes, and isosurfaces. For further information, refer to the User Guide.

With ERTLab *Studio* it is possible to visualize field data (*Measurements* Node) and inverted data (*Resistivity-Conductivity-IP*_Model node) in the same project.