

Res2DInv and Res3DInv

- Theory and demonstration

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Aarhus GeoSoftware

Program

- Theory
 - Introduction to DC and IP theory
 - Introduction to inversion theory
- Res2DInv and Res3DInv
 - Distribution and installation of software
 - 2D inversion and hands on exercises
 - Processing, inversion and troubleshooting
 - Presentation and visualization
 - 3D inversion and hands on exercises
 - Same procedure
 - Questions etc.

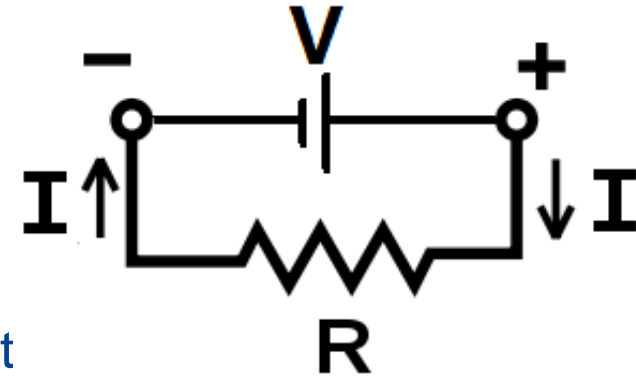
Terminology

- DC = Direct current method = ERT = Electrical Resistivity Tomography = ERI = Electrical resistivity Imaging etc.
- IP = induced polarization
- Processing = preparation of data before inversion
- Inversion = computation of geophysical model (resistivity and chargeability distribution) from measured data

Theory – Ohm's law

General formulation:

$$R = V/I$$

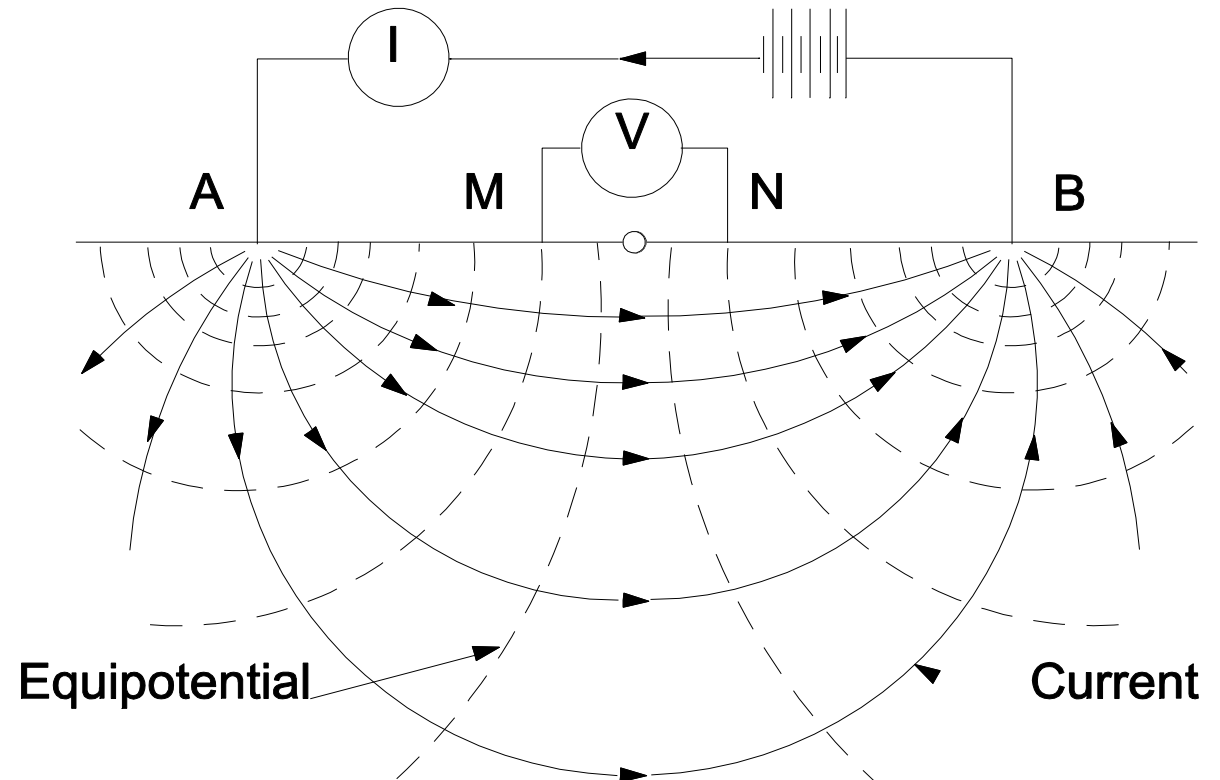
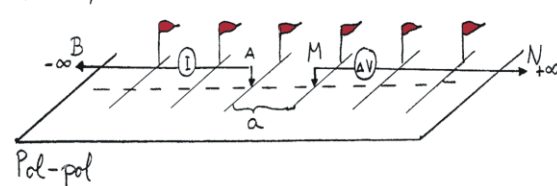
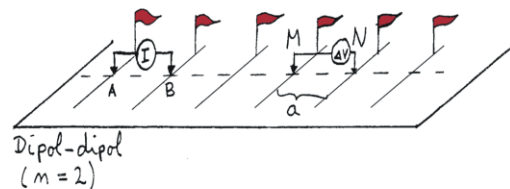
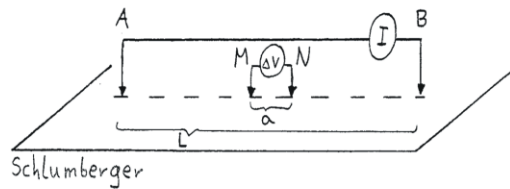
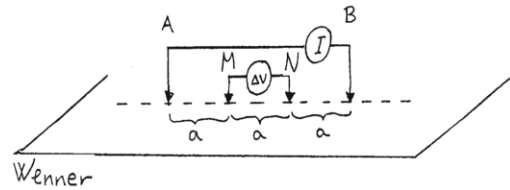


Geophysicists formulat

$$\rho_a = k \frac{\Delta V_{MN}}{I_{AB}}, \quad k = \frac{2\pi}{\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)}$$

Theory – Ohm's law

$$\rho_a = k \frac{\Delta V_{MN}}{I_{AB}}, \quad k = \frac{2\pi}{\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)}$$



How does current flow in the ground?

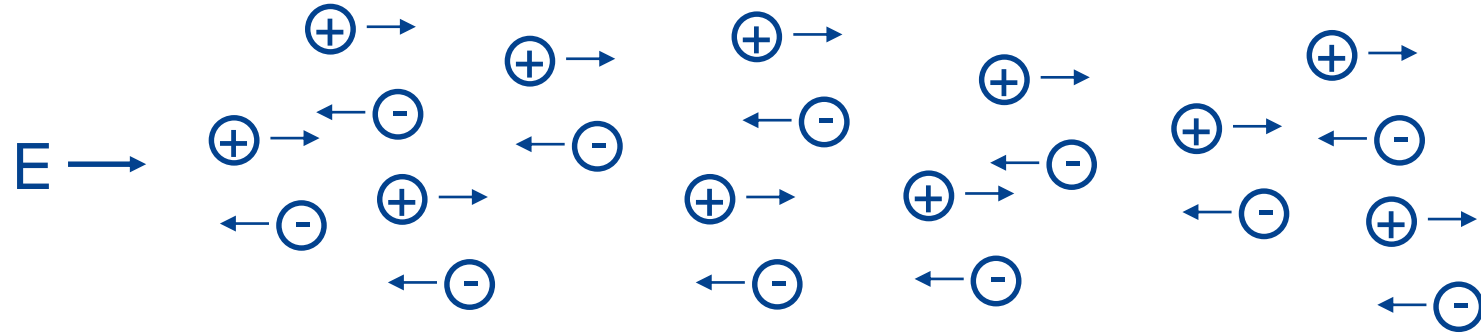
There are 3 main modes of current conduction in the subsurface, these are described by Archie's law:

- Bulk water
- Surface conduction
- Surface polarization

Archie's law: 3 current paths

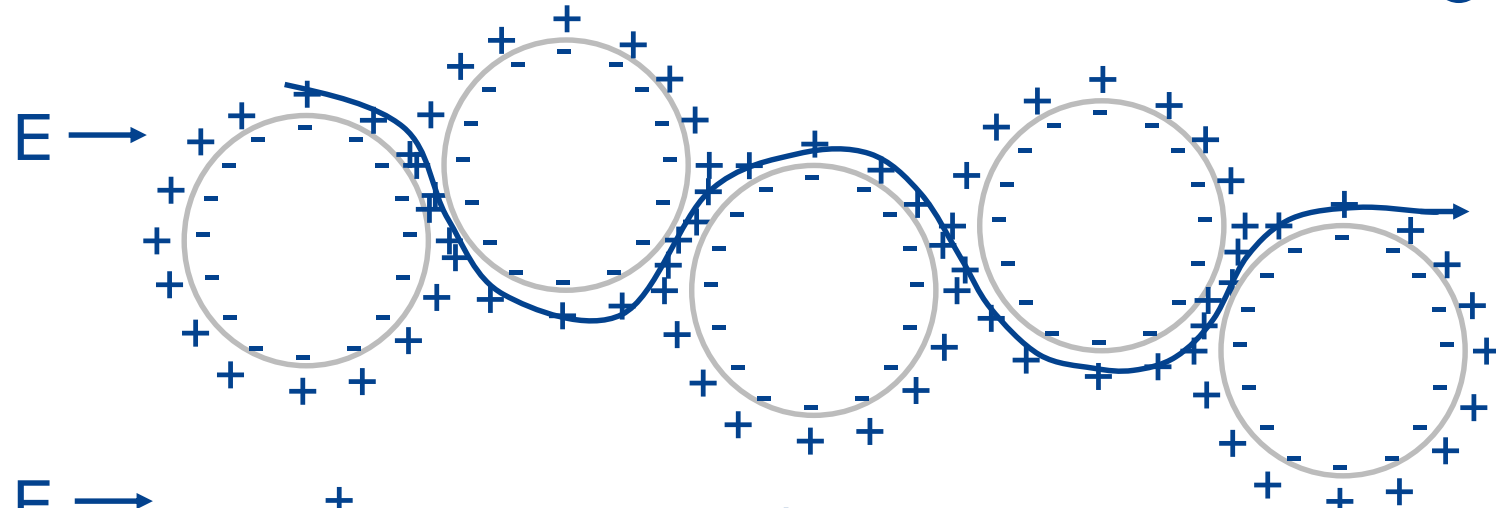
bulk water

$$\sigma = \frac{1}{F} \sigma_W$$



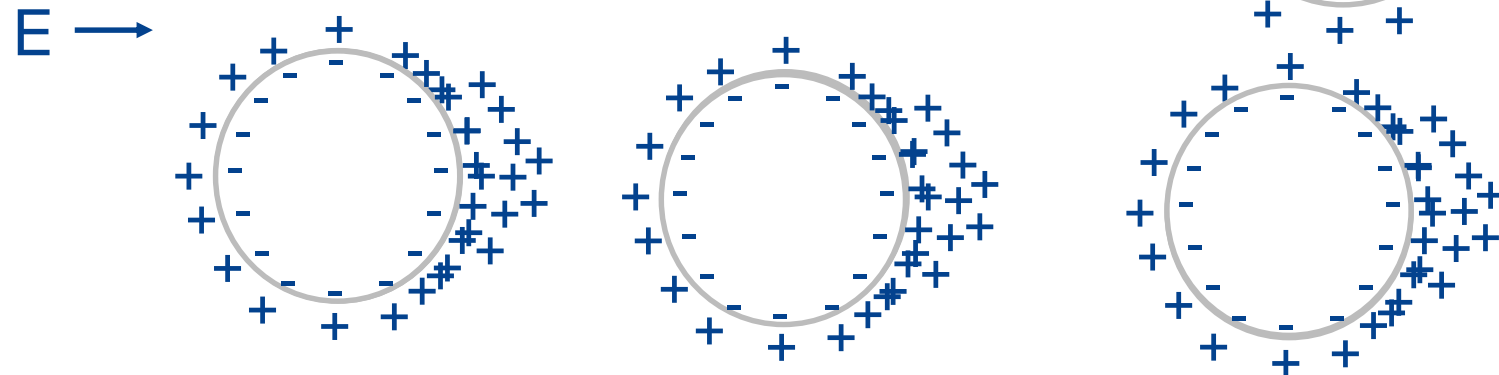
surface
conduction

$$\sigma = \sigma'_{surf}$$



surface (grain)
polarization

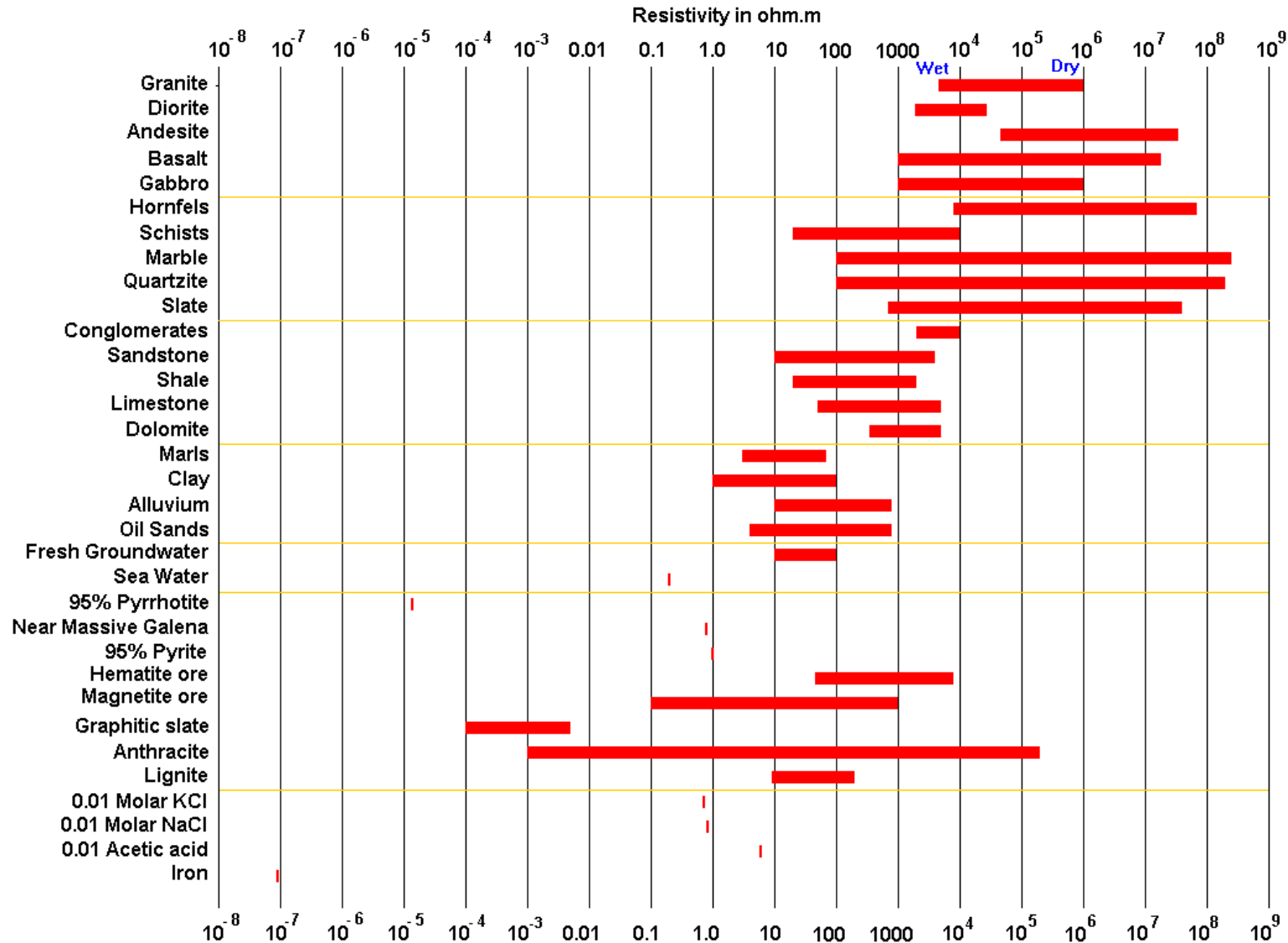
$$\sigma = i\sigma''_{surf}$$



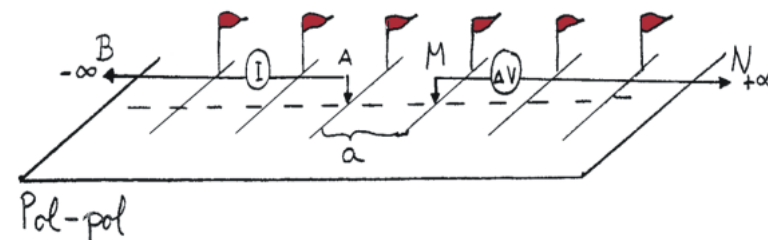
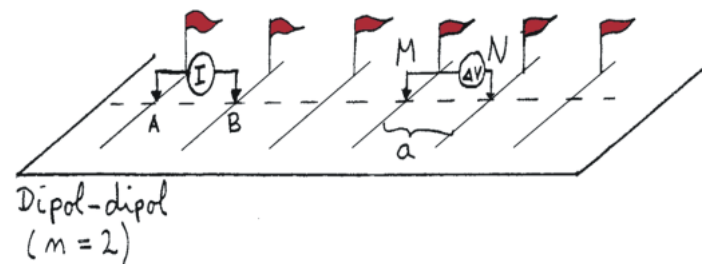
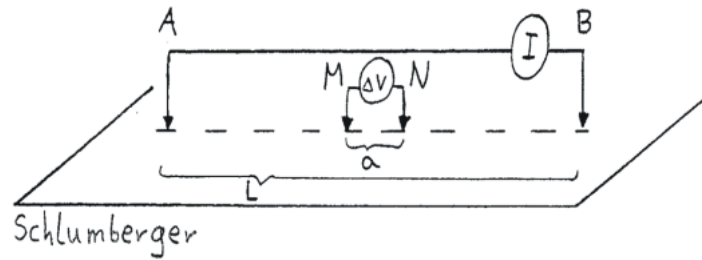
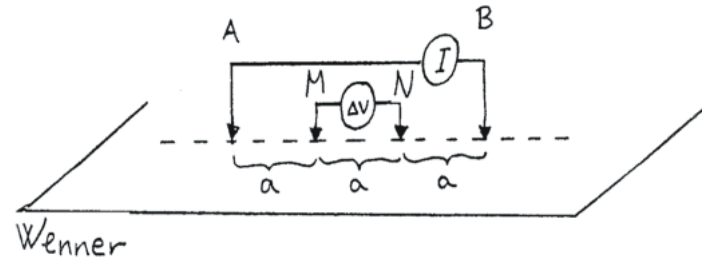
Archie's Law

$$\sigma = \begin{array}{c} \text{bulk water} \\ \frac{1}{F} \sigma_w \end{array} + \begin{array}{c} \text{surface} \\ \text{conduction} \\ \sigma'_{surf} \end{array} + \begin{array}{c} \text{surface} \\ \text{polarization} \\ i\sigma''_{surf} \end{array}$$

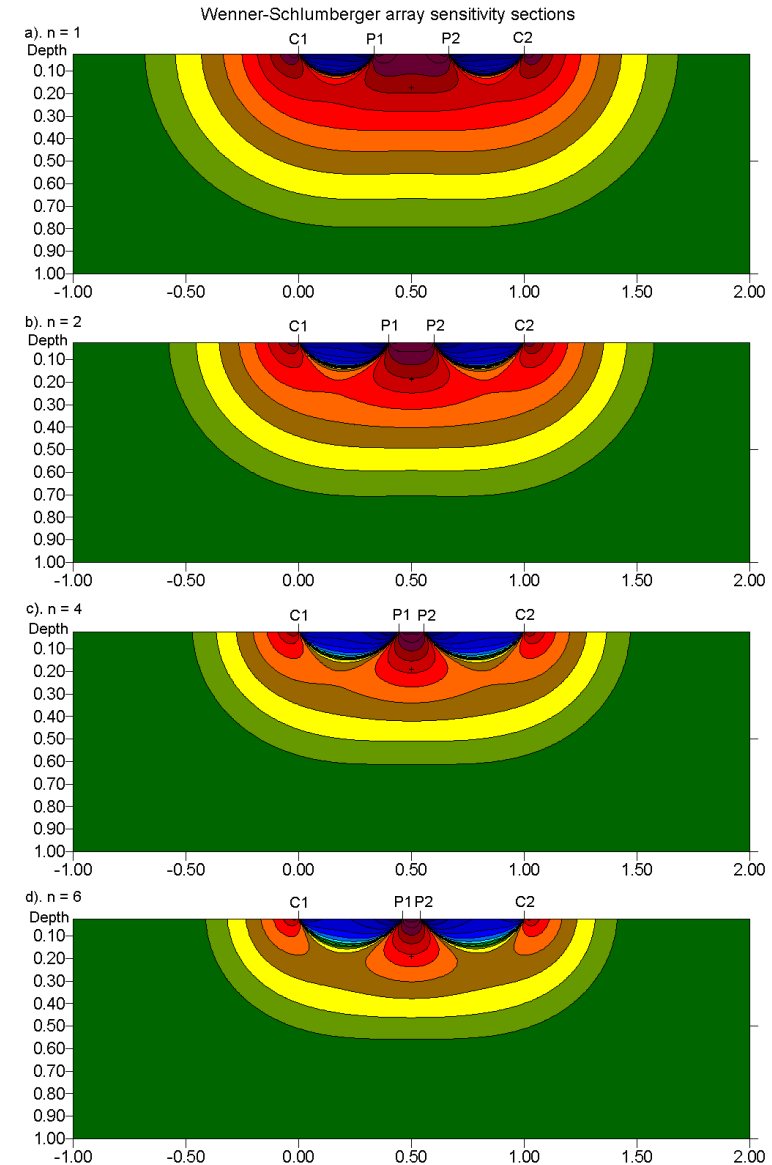
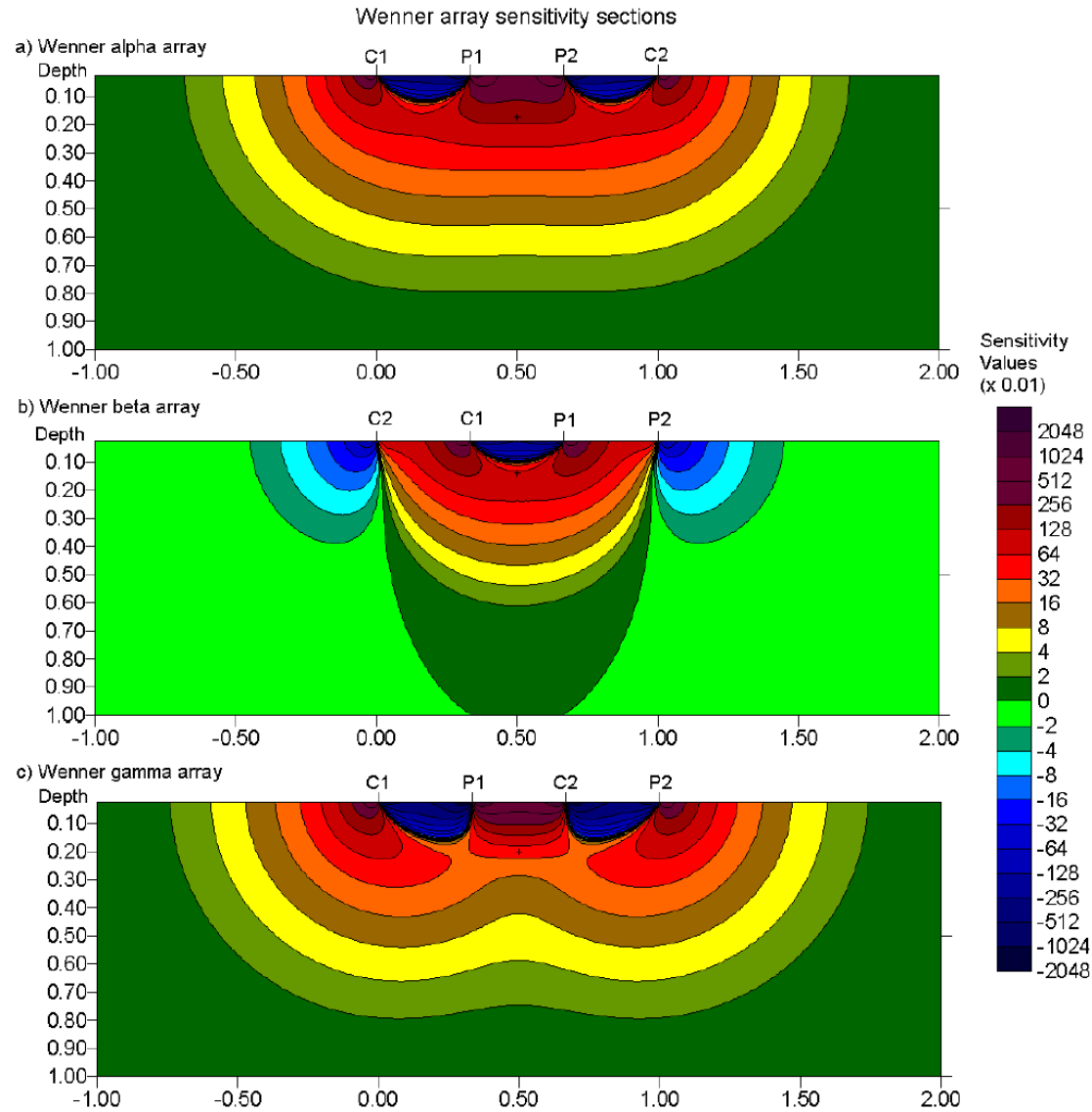
Examples of resistivities



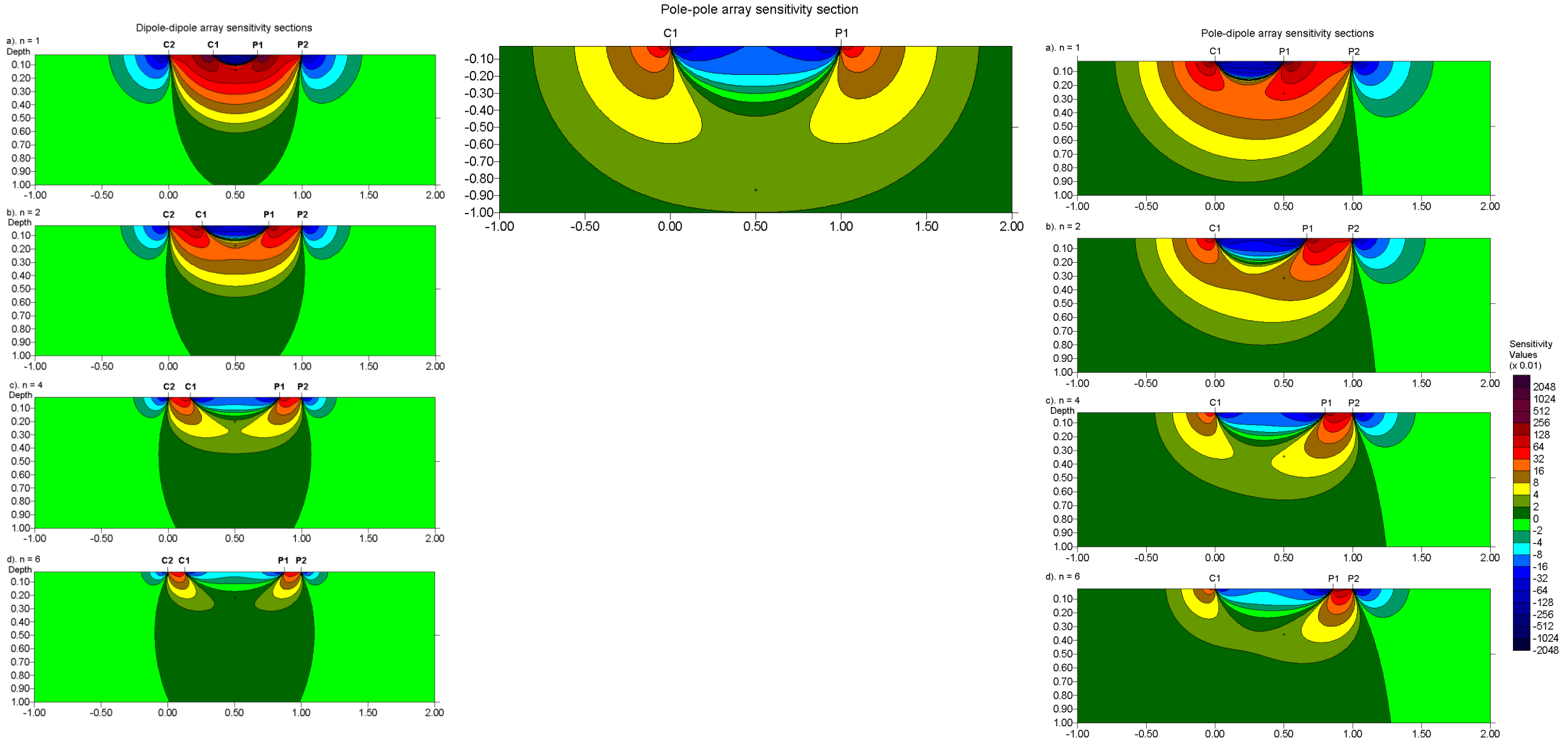
Sensitivity distribution of different configurations



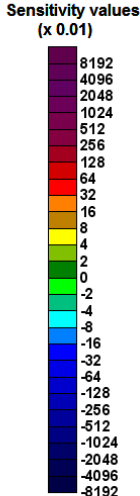
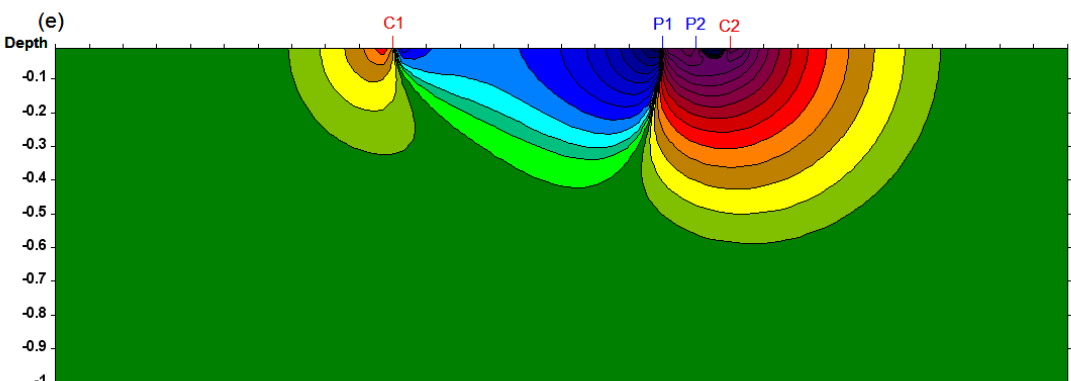
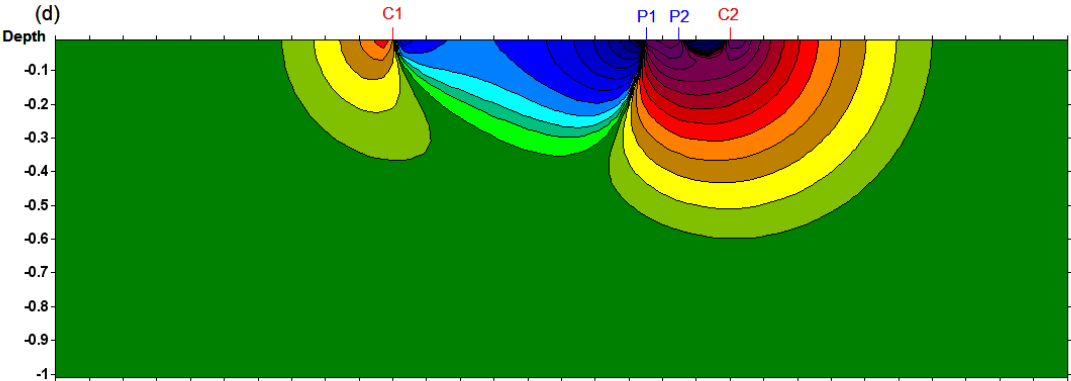
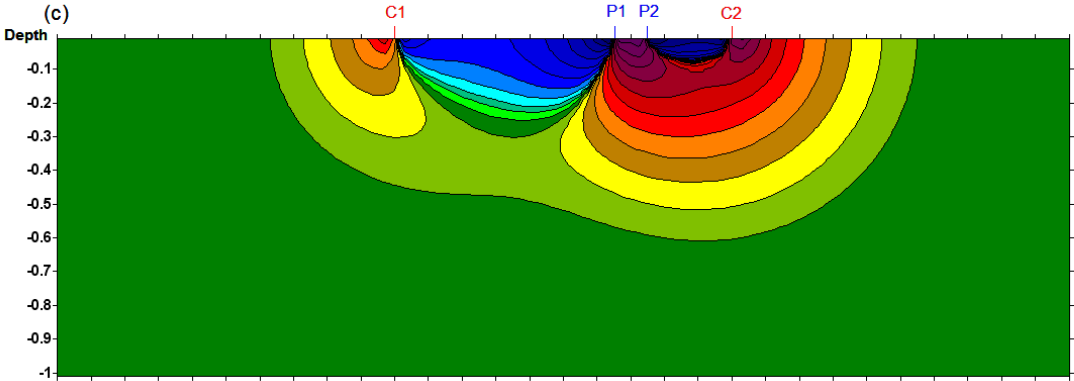
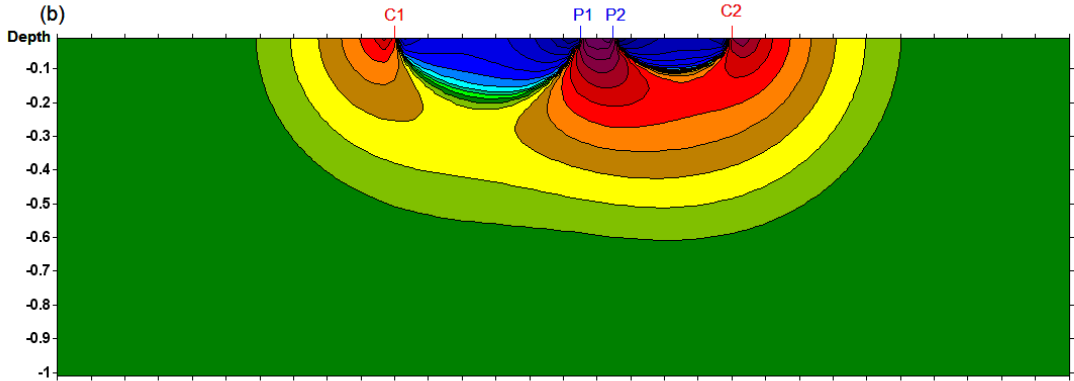
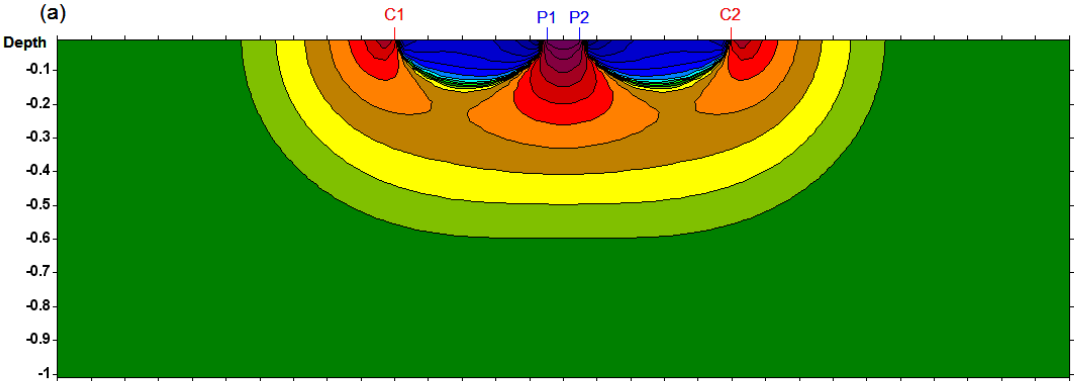
Sensitivity distribution of different configurations



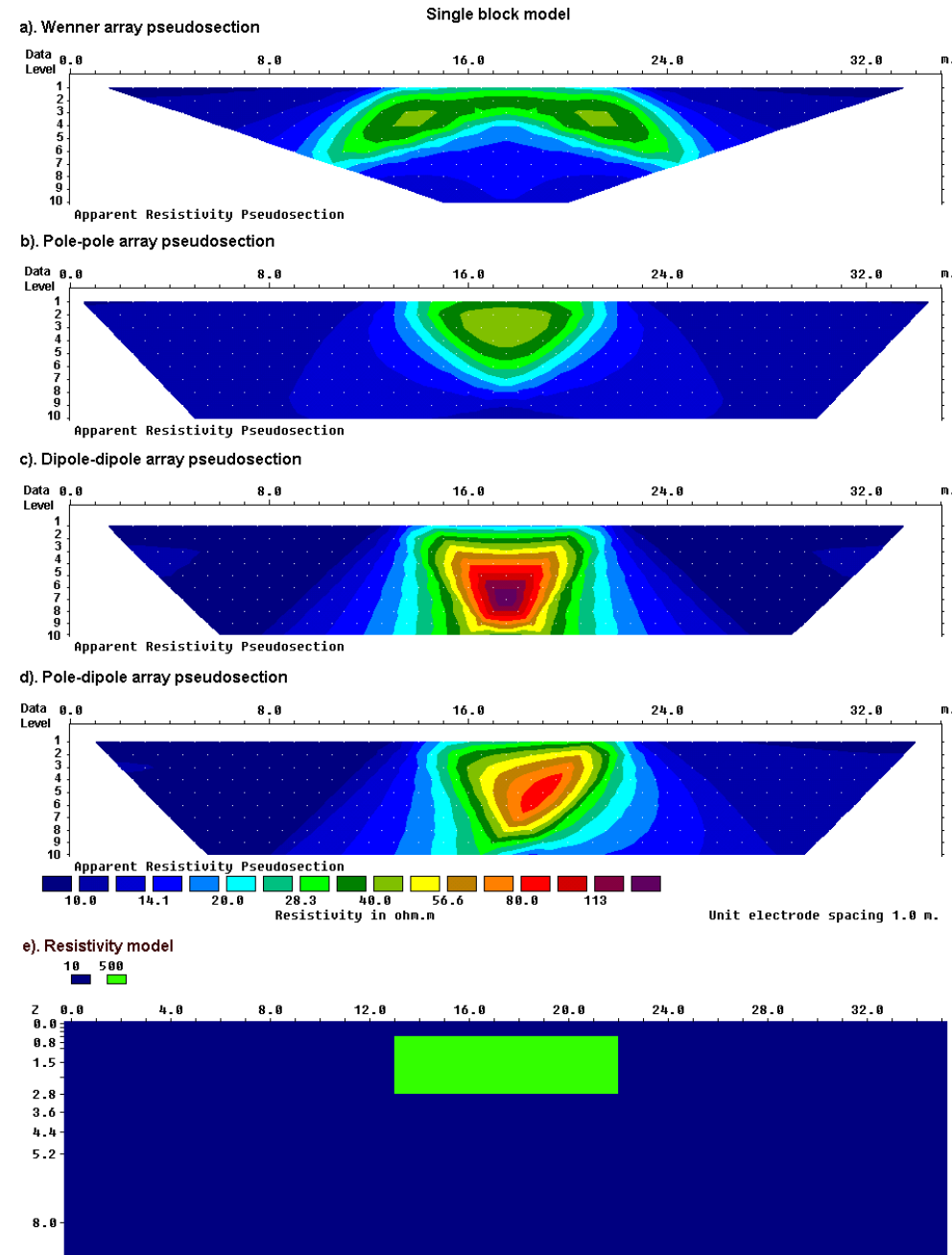
Sensitivity distribution of different configurations



Gradient Array



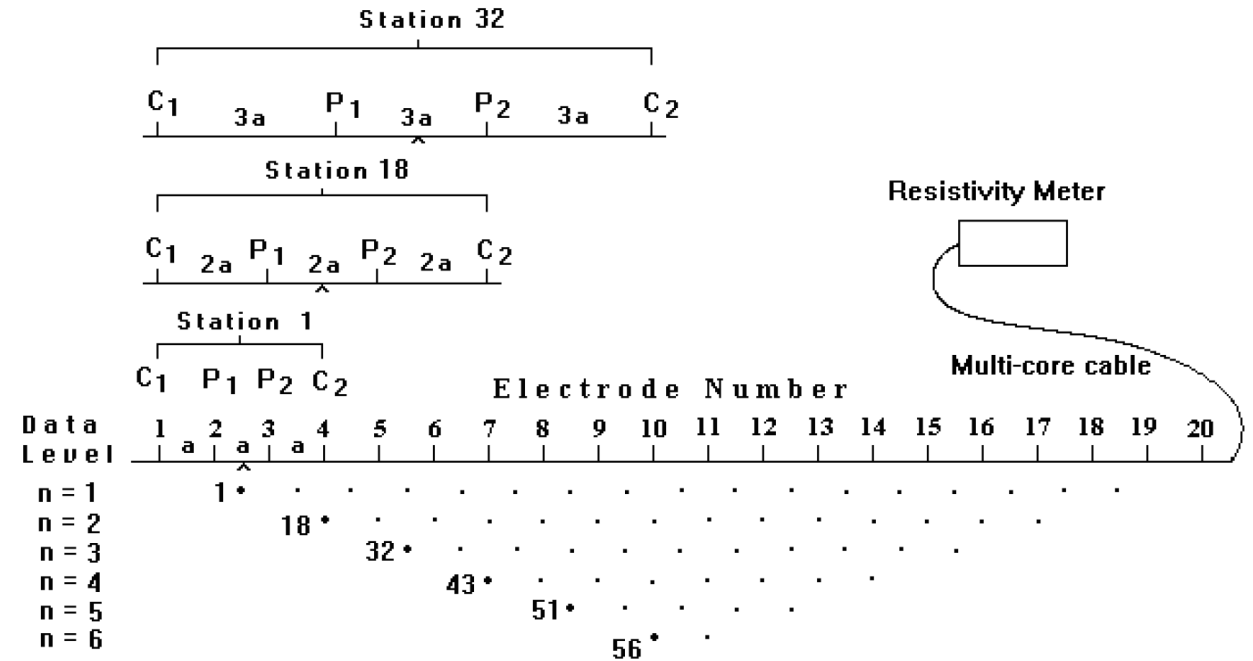
Pseudosection



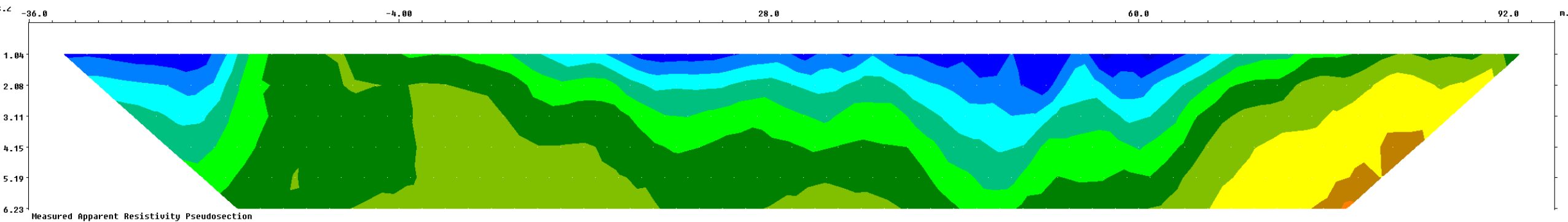
Inversion theory

What do we have?

A series of measurements of resistivity.



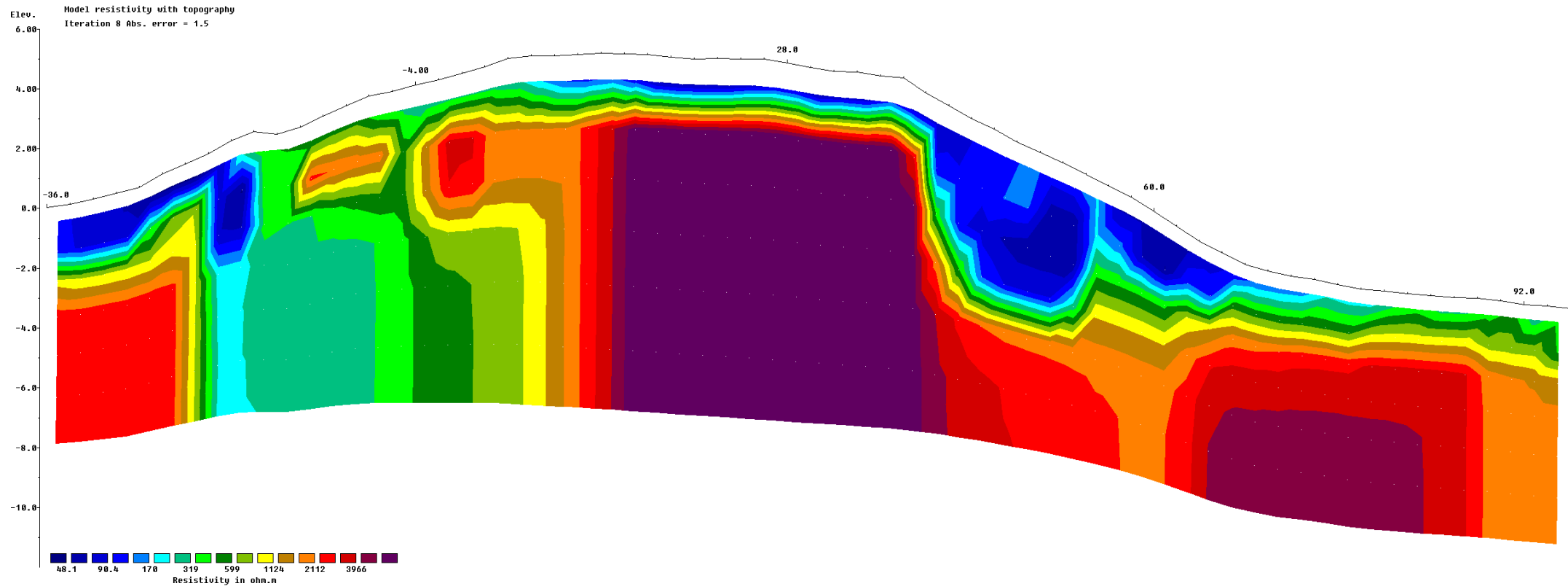
Sequence of measurements to build up a pseudosection



Inversion theory

What do we want?

A model of the resistivity distribution of the subsurface:



Inversion theory – how do we get there

Starting model

Forward calculation

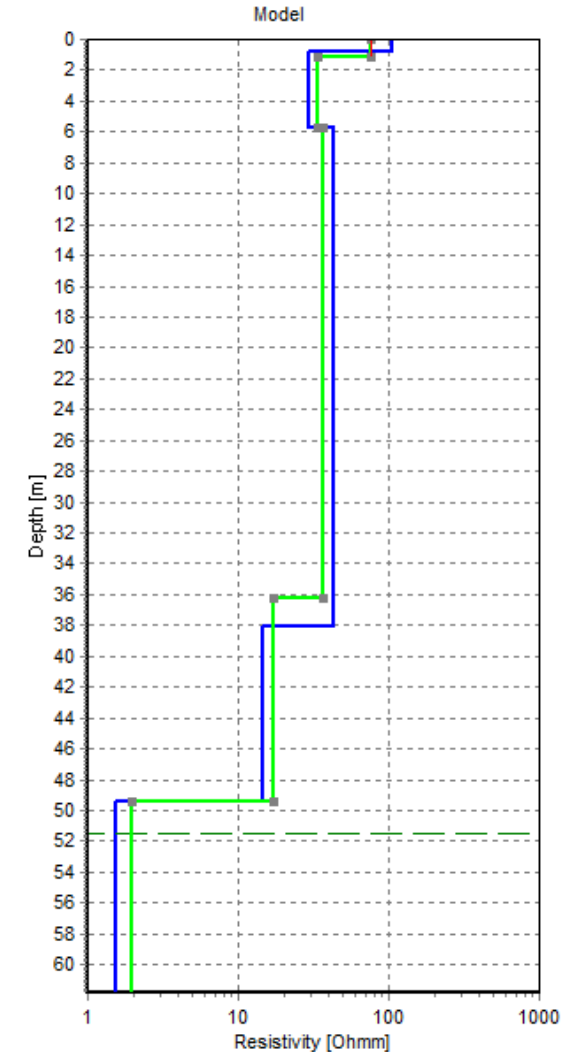
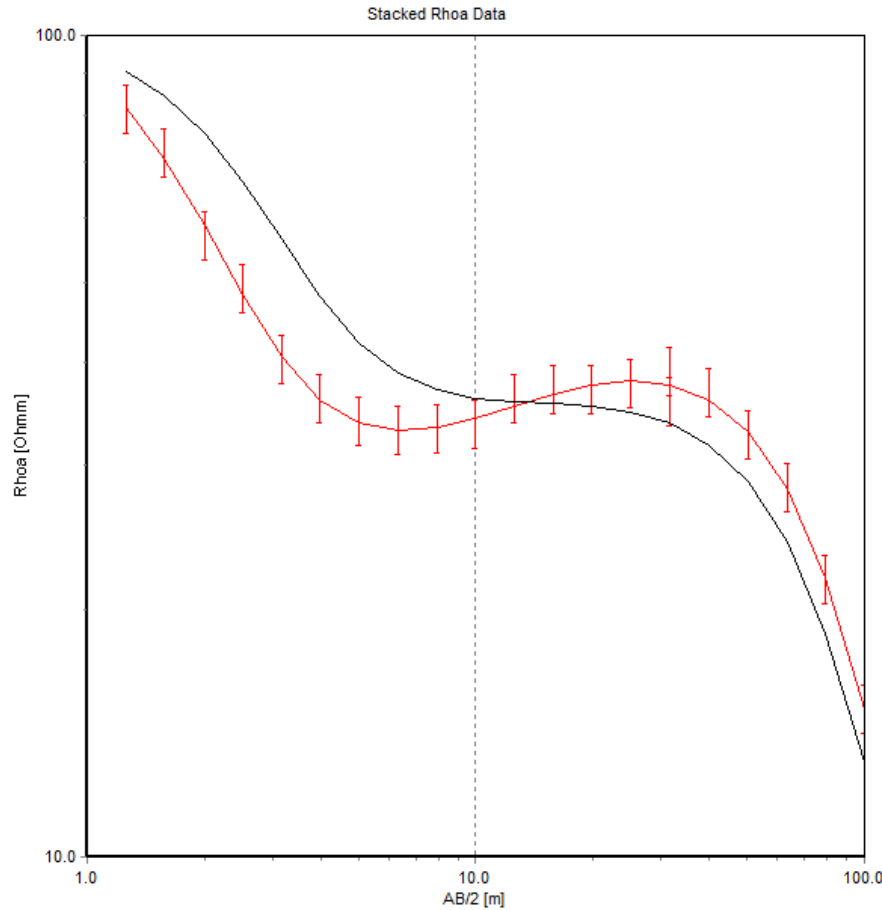
Comparison of forward calculation and measured data, is stopping criterion reached?

Yes

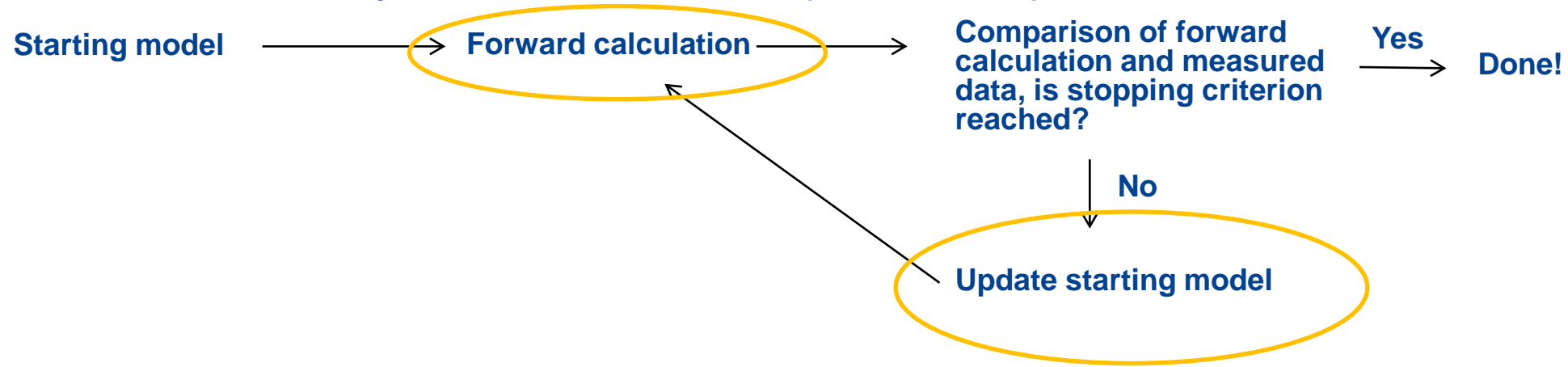
Done!

No

Update starting model



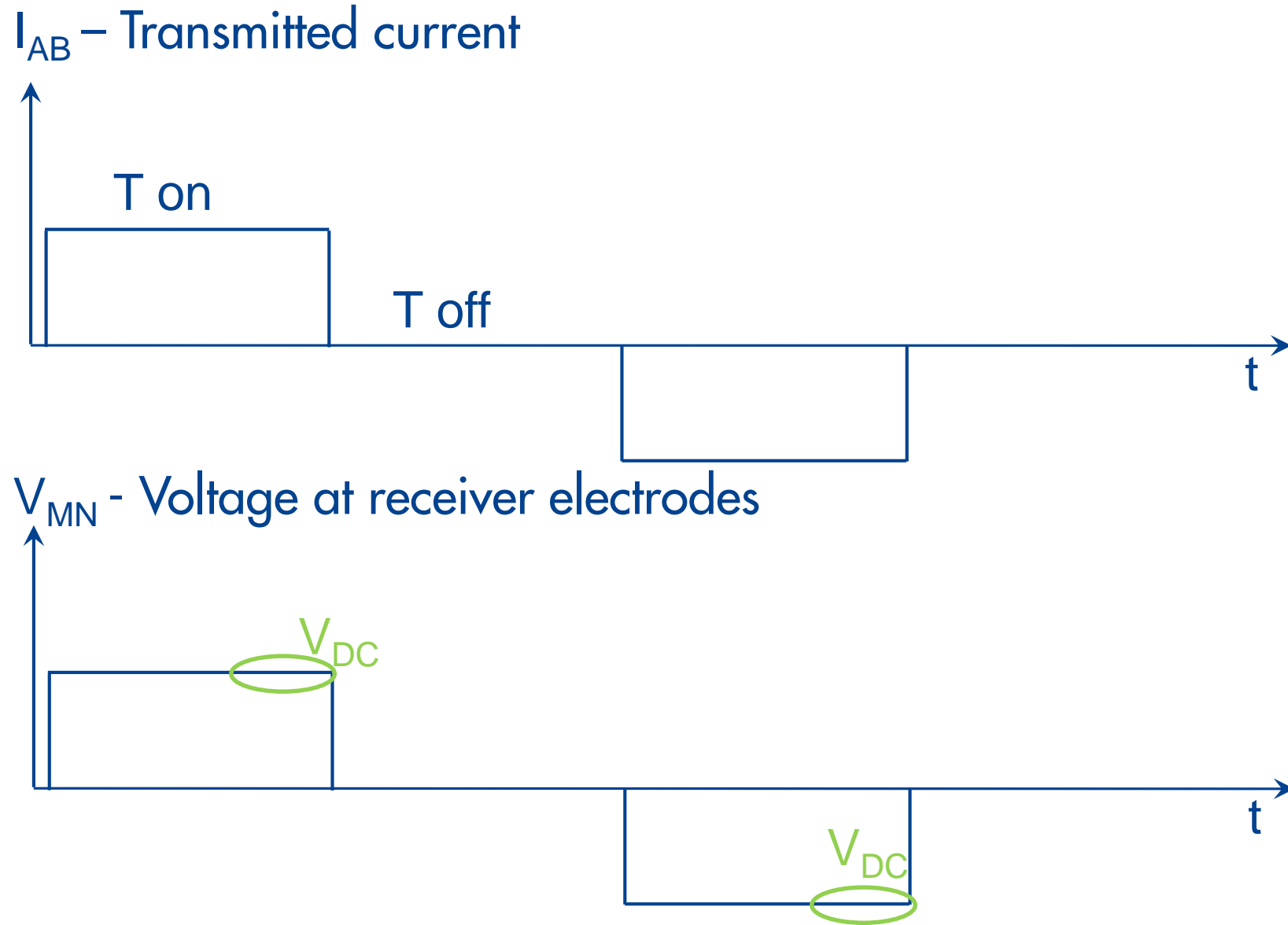
Inversion theory – looks easy... why is it so hard?



Induced polarization

- Induced polarization is the polarization of the subsurface as a result of the transmitted current
- The measurement and inversion principles for induced polarization are very similar to those of direct current methods, but the measured parameter is different
- Induced polarization can be useful in detecting minerals, and in distinguishing clay from other sediments with comparable resistivities

Induced polarization – No IP effect example

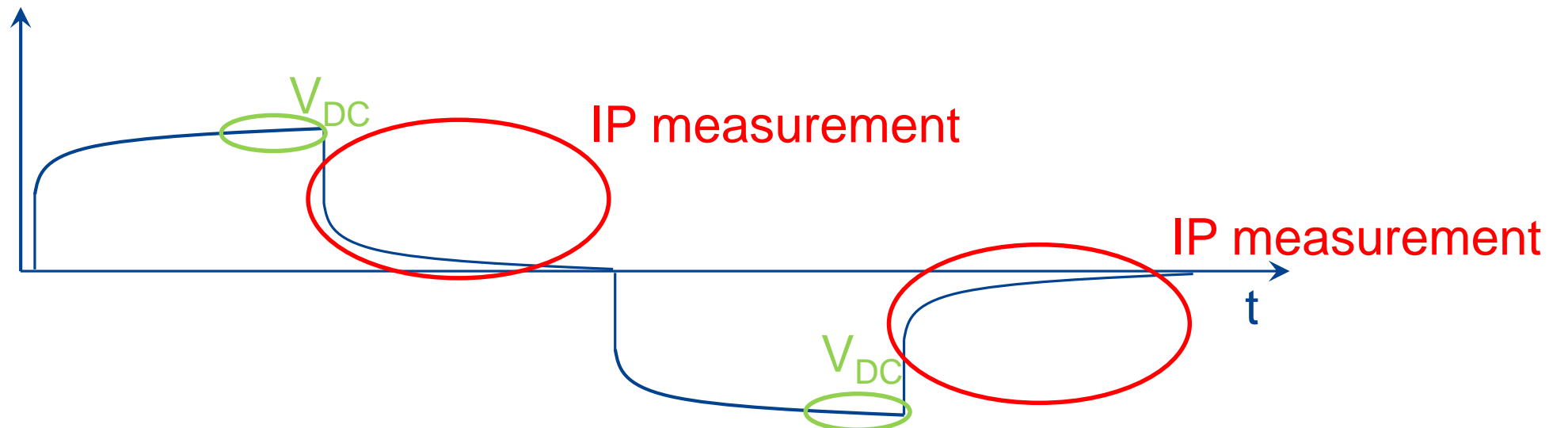


Induced polarization – Example with IP effects

I_{AB} – Transmitted current



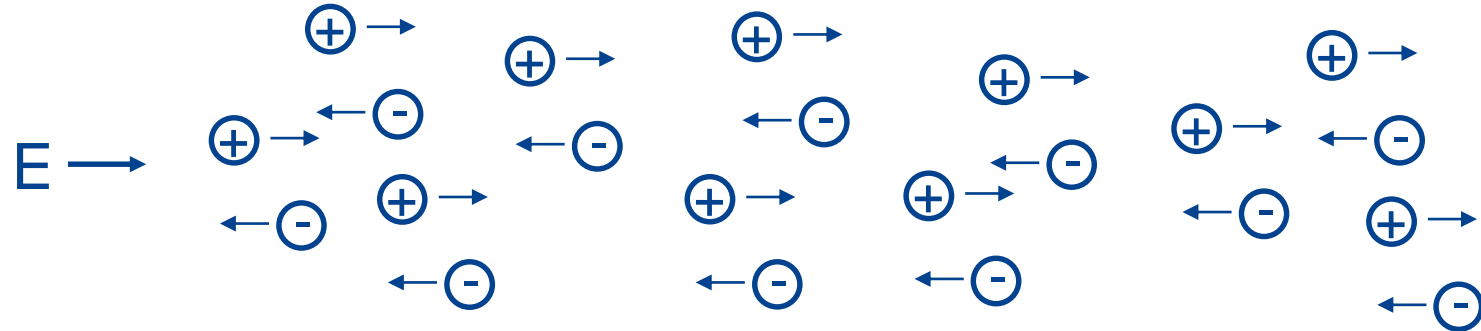
V_{MN} – Voltage at receiver electrodes



What causes the induced polarization effect?

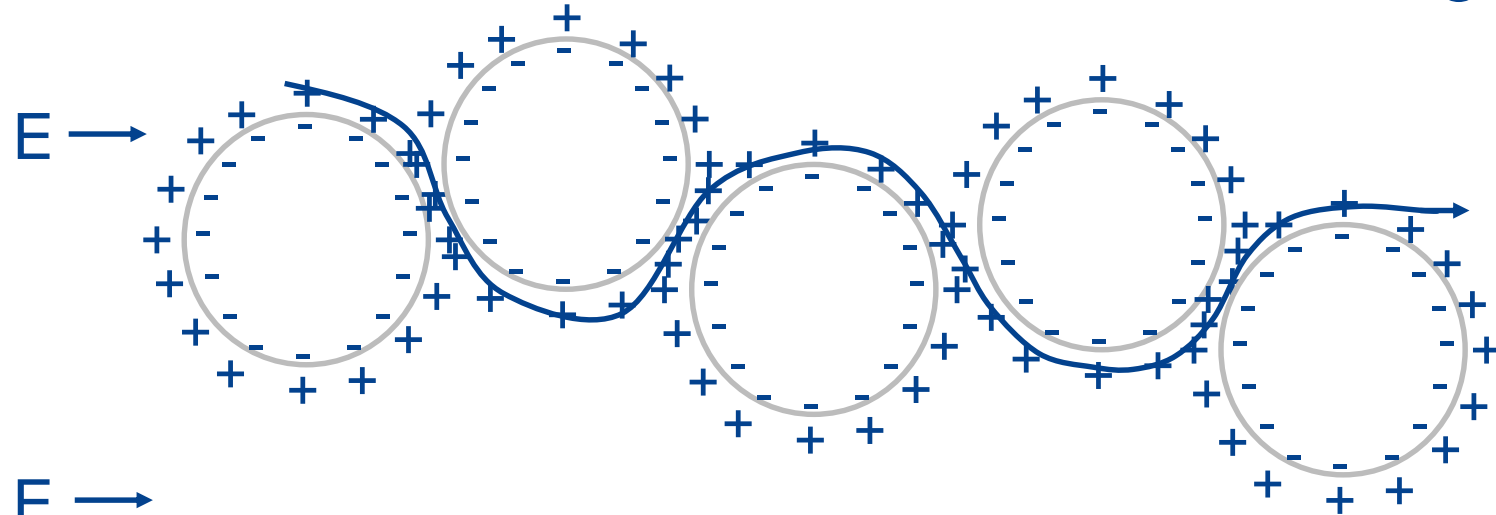
bulk water

$$\sigma = \frac{1}{F} \sigma_W$$



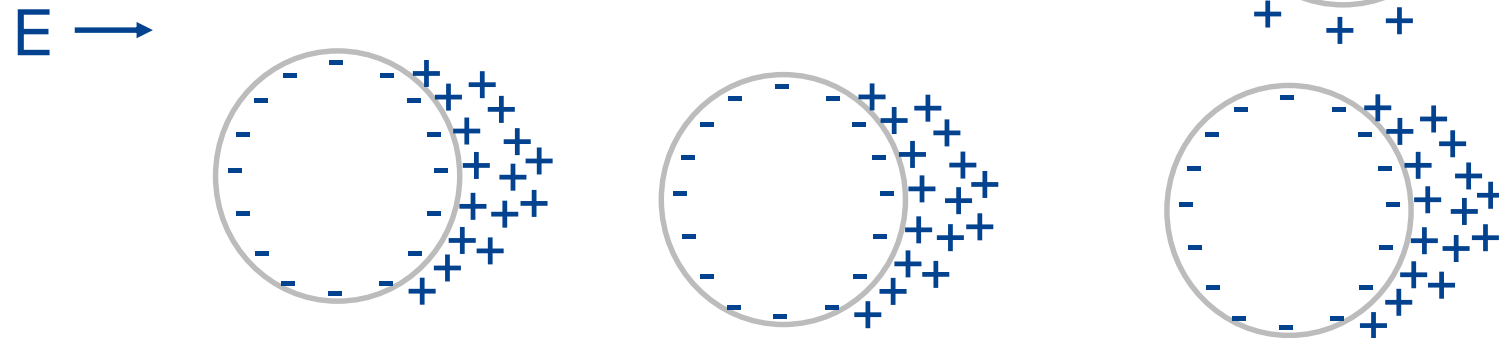
surface conduction

$$\sigma = \sigma'_{surf}$$



surface (grain) polarization

$$\sigma = i\sigma''_{surf}$$

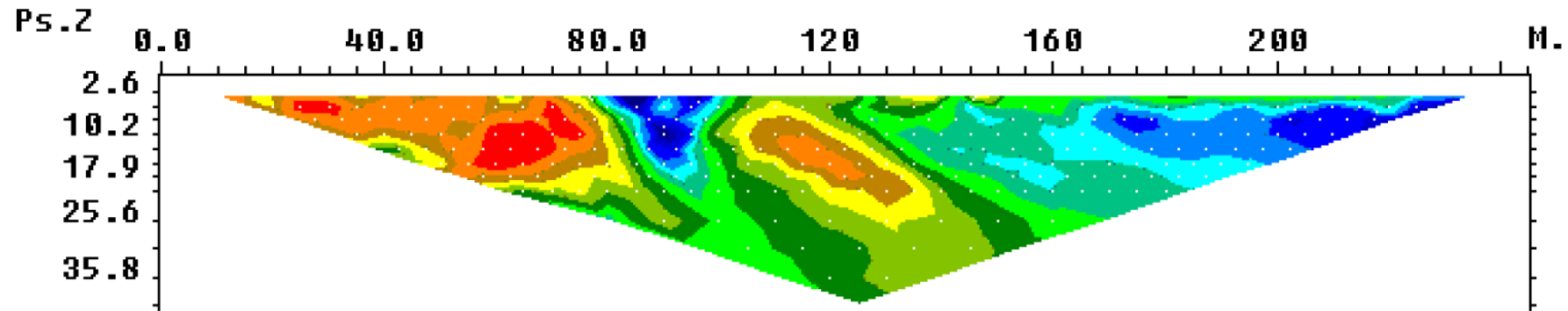


Interpretation

Key requirements for a successful interpretation of geophysical results:

- Good inversion result (low data misfit and correct inversion settings, we will get back to that)
- Good visualization of inversion results (correct axis and color scales, we will also get back to that)
- Prior general knowledge of the geology in the area
- Knowledge about expected resistivity ranges for geological bodies found in the area
- Any additional information if accessible (borehole logs and reports, other geophysical surveys)

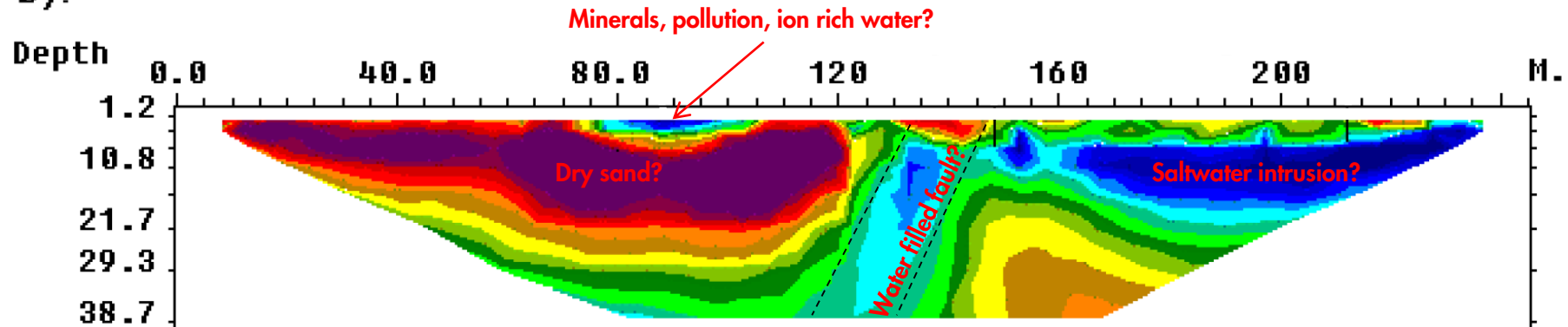
Interpretation – example



Measured Apparent Resistivity Pseudosection

Inversion model

b).



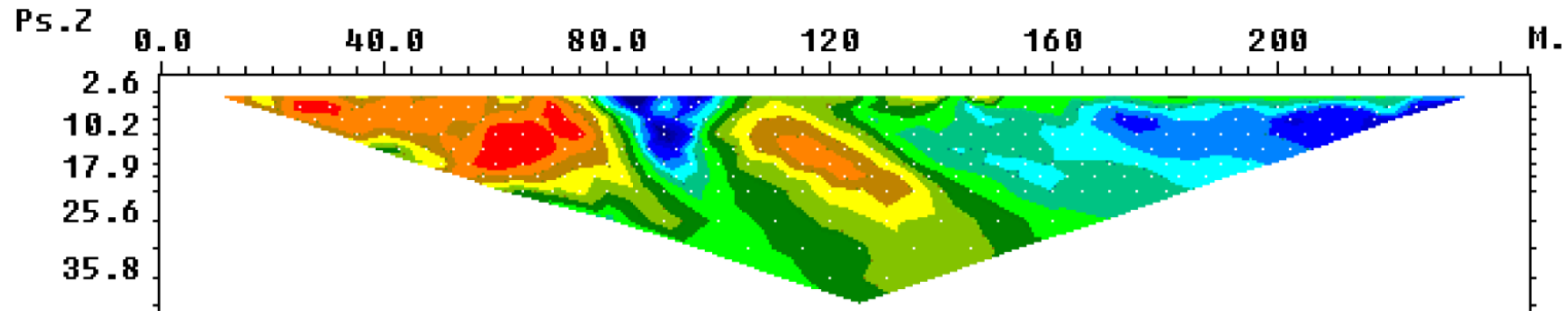
Inverse Model Resistivity Section



Resistivity in ohm.m

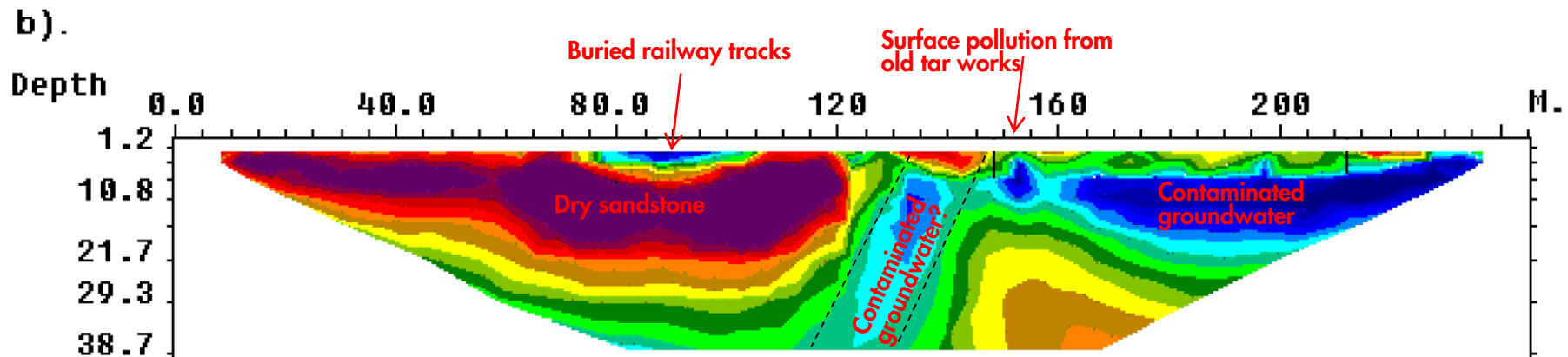
Unit electrode spacing 5.0 M.

Interpretation – example

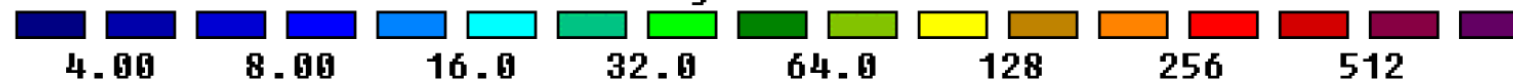


Measured Apparent Resistivity Pseudosection

Inversion model



Inverse Model Resistivity Section



Resistivity in ohm.m

Unit electrode spacing 5.0 M.

After the break – Res2DInv

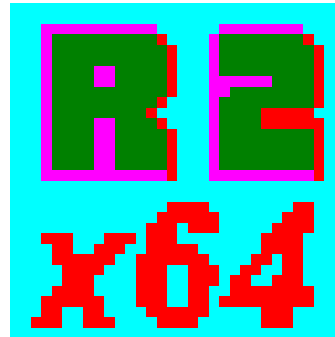
Res2DInv

Input: .dat file

- measured data
- a priori information
- coordinates, topography

.ivp file

- Inversion settings



Output: .inv file

- Models and forward calculations from all iterations
- Inversion settings
- Data

Hands on #1 – running a standard inversion

1. **Install Res2DInv**
2. **Register the license**
3. **Load `general_array_simple.dat` file by pressing “File -> Read data file” and selecting the file**
4. **Run a simple inversion by pressing “Inversion -> carry out inversion” and select where to save the inversion result**

The .dat file – simple example

Header lines

Data lines

```

1 General array format example Comment/title line
2 1.0 Unit electrode distance
3 11 Array type (General array)
4 0 Array sub-type (unspecified)
5 Type of measurement (0=app. resistivity,1=resistance) Header
6 0 Measurement type indication
7 407 Number of data points
8 1 Format of x-coordinates (0 or 1 for true horizontal distances)
9 0 Flag for IP data
10 4 0.00 0.00 3.00 0.00 1.00 0.00 2.00 0.00 10.158
11 4 1.00 0.00 4.00 0.00 2.00 0.00 3.00 0.00 10.168
12 4 2.00 0.00 5.00 0.00 3.00 0.00 4.00 0.00 10.184
13 4 3.00 0.00 6.00 0.00 4.00 0.00 5.00 0.00 10.225
14 4 4.00 0.00 7.00 0.00 5.00 0.00 6.00 0.00 10.337
15 4 5.00 0.00 8.00 0.00 6.00 0.00 7.00 0.00 10.708
16 4 6.00 0.00 9.00 0.00 7.00 0.00 8.00 0.00 11.668
17 4 7.00 0.00 10.00 0.00 8.00 0.00 9.00 0.00 12.542
18 4 8.00 0.00 11.00 0.00 9.00 0.00 10.00 0.00 12.871
19 4 9.00 0.00 12.00 0.00 10.00 0.00 11.00 0.00 13.238
20 4 10.00 0.00 13.00 0.00 11.00 0.00 12.00 0.00 13.342
21 4 11.00 0.00 14.00 0.00 12.00 0.00 13.00 0.00 13.331
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113 4 103.00 0.00 106.00 0.00 104.00 0.00 105.00 0.00 13.331
114 4 104.00 0.00 107.00 0.00 105.00 0.00 106.00 0.00 13.331
115 4 105.00 0.00 108.00 0.00 106.00 0.00 107.00 0.00 13.331
116 4 106.00 0.00 109.00 0.00 107.00 0.00 108.00 0.00 13.331
117 4 107.00 0.00 110.00 0.00 108.00 0.00 109.00 0.00 13.331
118 4 108.00 0.00 111.00 0.00 109.00 0.00 110.00 0.00 13.331
119 4 109.00 0.00 112.00 0.00 110.00 0.00 111.00 0.00 13.331
120 4 110.00 0.00 113.00 0.00 111.00 0.00 112.00 0.00 13.331
121 4 111.00 0.00 114.00 0.00 112.00 0.00 113.00 0.00 13.331
122 4 112.00 0.00 115.00 0.00 113.00 0.00 114.00 0.00 13.331
123 4 113.00 0.00 116.00 0.00 114.00 0.00 115.00 0.00 13.331
124 4 114.00 0.00 117.00 0.00 115.00 0.00 116.00 0.00 13.331
125 4 115.00 0.00 118.00 0.00 116.00 0.00 117.00 0.00 13.331
126 4 116.00 0.00 119.00 0.00 117.00 0.00 118.00 0.00 13.331
127 4 117.00 0.00 120.00 0.00 118.00 0.00 119.00 0.00 13.331
128 4 118.00 0.00 121.00 0.00 119.00 0.00 120.00 0.00 13.331
129 4 119.00 0.00 122.00 0.00 120.00 0.00 121.00 0.00 13.331
130 4 120.00 0.00 123.00 0.00 121.00 0.00 122.00 0.00 13.331
131 4 121.00 0.00 124.00 0.00 122.00 0.00 123.00 0.00 13.331
132 4 122.00 0.00 125.00 0.00 123.00 0.00 124.00 0.00 13.331
133 4 123.00 0.00 126.00 0.00 124.00 0.00 125.00 0.00 13.331
134 4 124.00 0.00 127.00 0.00 125.00 0.00 126.00 0.00 13.331
135 4 125.00 0.00 128.00 0.00 126.00 0.00 127.00 0.00 13.331
136 4 126.00 0.00 129.00 0.00 127.00 0.00 128.00 0.00 13.331
137 4 127.00 0.00 130.00 0.00 128.00 0.00 129.00 0.00 13.331
138 4 128.00 0.00 131.00 0.00 129.00 0.00 130.00 0.00 13.331
139 4 129.00 0.00 132.00 0.00 130.00 0.00 131.00 0.00 13.331
140 4 130.00 0.00 133.00 0.00 131.00 0.00 132.00 0.00 13.331
141 4 131.00 0.00 134.00 0.00 132.00 0.00 133.00 0.00 13.331
142 4 132.00 0.00 135.00 0.00 133.00 0.00 134.00 0.00 13.331
143 4 133.00 0.00 136.00 0.00 134.00 0.00 135.00 0.00 13.331
144 4 134.00 0.00 137.00 0.00 135.00 0.00 136.00 0.00 13.331
145 4 135.00 0.00 138.00 0.00 136.00 0.00 137.00 0.00 13.331
146 4 136.00 0.00 139.00 0.00 137.00 0.00 138.00 0.00 13.331
147 4 137.00 0.00 140.00 0.00 138.00 0.00 139.00 0.00 13.331
148 4 138.00 0.00 141.00 0.00 139.00 0.00 140.00 0.00 13.331
149 4 139.00 0.00 142.00 0.00 140.00 0.00 141.00 0.00 13.331
150 4 140.00 0.00 143.00 0.00 141.00 0.00 142.00 0.00 13.331
151 4 141.00 0.00 144.00 0.00 142.00 0.00 143.00 0.00 13.331
152 4 142.00 0.00 145.00 0.00 143.00 0.00 144.00 0.00 13.331
153 4 143.00 0.00 146.00 0.00 144.00 0.00 145.00 0.00 13.331
154 4 144.00 0.00 147.00 0.00 145.00 0.00 146.00 0.00 13.331
155 4 145.00 0.00 148.00 0.00 146.00 0.00 147.00 0.00 13.331
156 4 146.00 0.00 149.00 0.00 147.00 0.00 148.00 0.00 13.331
157 4 147.00 0.00 150.00 0.00 148.00 0.00 149.00 0.00 13.331
158 4 148.00 0.00 151.00 0.00 149.00 0.00 150.00 0.00 13.331
159 4 149.00 0.00 152.00 0.00 150.00 0.00 151.00 0.00 13.331
160 4 150.00 0.00 153.00 0.00 151.00 0.00 152.00 0.00 13.331
161 4 151.00 0.00 154.00 0.00 152.00 0.00 153.00 0.00 13.331
162 4 152.00 0.00 155.00 0.00 153.00 0.00 154.00 0.00 13.331
163 4 153.00 0.00 156.00 0.00 154.00 0.00 155.00 0.00 13.331
164 4 154.00 0.00 157.00 0.00 155.00 0.00 156.00 0.00 13.331
165 4 155.00 0.00 158.00 0.00 156.00 0.00 157.00 0.00 13.331
166 4 156.00 0.00 159.00 0.00 157.00 0.00 158.00 0.00 13.331
167 4 157.00 0.00 160.00 0.00 158.00 0.00 159.00 0.00 13.331
168 4 158.00 0.00 161.00 0.00 159.00 0.00 160.00 0.00 13.331
169 4 159.00 0.00 162.00 0.00 160.00 0.00 161.00 0.00 13.331
170 4 160.00 0.00 163.00 0.00 161.00 0.00 162.00 0.00 13.331
171 4 161.00 0.00 164.00 0.00 162.00 0.00 163.00 0.00 13.331
172 4 162.00 0.00 165.00 0.00 163.00 0.00 164.00 0.00 13.331
173 4 163.00 0.00 166.00 0.00 164.00 0.00 165.00 0.00 13.331
174 4 164.00 0.00 167.00 0.00 165.00 0.00 166.00 0.00 13.331
175 4 165.00 0.00 168.00 0.00 166.00 0.00 167.00 0.00 13.331
176 4 166.00 0.00 169.00 0.00 167.00 0.00 168.00 0.00 13.331
177 4 167.00 0.00 170.00 0.00 168.00 0.00 169.00 0.00 13.331
178 4 168.00 0.00 171.00 0.00 169.00 0.00 170.00 0.00 13.331
179 4 169.00 0.00 172.00 0.00 170.00 0.00 171.00 0.00 13.331
180 4 170.00 0.00 173.00 0.00 171.00 0.00 172.00 0.00 13.331
181 4 171.00 0.00 174.00 0.00 172.00 0.00 173.00 0.00 13.331
182 4 172.00 0.00 175.00 0.00 173.00 0.00 174.00 0.00 13.331
183 4 173.00 0.00 176.00 0.00 174.00 0.00 175.00 0.00 13.331
184 4 174.00 0.00 177.00 0.00 175.00 0.00 176.00 0.00 13.331
185 4 175.00 0.00 178.00 0.00 176.00 0.00 177.00 0.00 13.331
186 4 176.00 0.00 179.00 0.00 177.00 0.00 178.00 0.00 13.331
187 4 177.00 0.00 180.00 0.00 178.00 0.00 179.00 0.00 13.331
188 4 178.00 0.00 181.00 0.00 179.00 0.00 180.00 0.00 13.331
189 4 179.00 0.00 182.00 0.00 180.00 0.00 181.00 0.00 13.331
190 4 180.00 0.00 183.00 0.00 181.00 0.00 182.00 0.00 13.331
191 4 181.00 0.00 184.00 0.00 182.00 0.00 183.00 0.00 13.331
192 4 182.00 0.00 185.00 0.00 183.00 0.00 184.00 0.00 13.331
193 4 183.00 0.00 186.00 0.00 184.00 0.00 185.00 0.00 13.331
194 4 184.00 0.00 187.00 0.00 185.00 0.00 186.00 0.00 13.331
195 4 185.00 0.00 188.00 0.00 186.00 0.00 187.00 0.00 13.331
196 4 186.00 0.00 189.00 0.00 187.00 0.00 188.00 0.00 13.331
197 4 187.00 0.00 190.00 0.00 188.00 0.00 189.00 0.00 13.331
198 4 188.00 0.00 191.00 0.00 189.00 0.00 190.00 0.00 13.331
199 4 189.00 0.00 192.00 0.00 190.00 0.00 191.00 0.00 13.331
200 4 190.00 0.00 193.00 0.00 191.00 0.00 192.00 0.00 13.331
201 4 191.00 0.00 194.00 0.00 192.00 0.00 193.00 0.00 13.331
202 4 192.00 0.00 195.00 0.00 193.00 0.00 194.00 0.00 13.331
203 4 193.00 0.00 196.00 0.00 194.00 0.00 195.00 0.00 13.331
204 4 194.00 0.00 197.00 0.00 195.00 0.00 196.00 0.00 13.331
205 4 195.00 0.00 198.00 0.00 196.00 0.00 197.00 0.00 13.331
206 4 196.00 0.00 199.00 0.00 197.00 0.00 198.00 0.00 13.331
207 4 197.00 0.00 200.00 0.00 198.00 0.00 199.00 0.00 13.331
208 4 198.00 0.00 201.00 0.00 199.00 0.00 200.00 0.00 13.331
209 4 199.00 0.00 202.00 0.00 200.00 0.00 201.00 0.00 13.331
210 4 200.00 0.00 203.00 0.00 201.00 0.00 202.00 0.00 13.331
211 4 201.00 0.00 204.00 0.00 202.00 0.00 203.00 0.00 13.331
212 4 202.00 0.00 205.00 0.00 203.00 0.00 204.00 0.00 13.331
213 4 203.00 0.00 206.00 0.00 204.00 0.00 205.00 0.00 13.331
214 4 204.00 0.00 207.00 0.00 205.00 0.00 206.00 0.00 13.331
215 4 205.00 0.00 208.00 0.00 206.00 0.00 207.00 0.00 13.331
216 4 206.
```

The .dat file – special formats

1. Induced polarization
2. Pole-pole and pole-dipole arrays
3. Topography
4. Global coordinates
5. Surveys in water
6. Cross borehole data and buried electrodes
7. Known boundaries and fixed regions



The .dat file – IP data

```

1 General array with IP Comment/title line
2 1.0 Unit electrode distance
3 11 Array type
4 0 Array sub-type
5 Type of measurement (0=app. resistivity,1=resistance)Header
6 0 Measurement type indication
7 228 Number of data points
8 1 Format of x-coordinates (0 or 1 for true horizontal distances)
9 1 Flag for IP data
10 Chargeability Type of IP data
11 mV/V IP data unit
12 0.0,1.0 Delay, Integration time
13 4 1.00 0.00 0.00 0.00 2.00 0.00 3.00 0.00 13.301 12.5858
14 4 2.00 0.00 1.00 0.00 3.00 0.00 4.00 0.00 13.298 12.5886
15 4 3.00 0.00 2.00 0.00 4.00 0.00 5.00 0.00 13.297 12.5867
16 4 4.00 0.00 3.00 0.00 5.00 0.00 6.00 0.00 13.297 12.5917
17 4 5.00 0.00 4.00 0.00 6.00 0.00 7.00 0.00 13.297 12.5953
18 4 6.00 0.00 5.00 0.00 7.00 0.00 8.00 0.00 13.297 12.6043
19 4 7.00 0.00 6.00 0.00 8.00 0.00 9.00 0.00 13.299 12.6218
20 4 8.00 0.00 7.00 0.00 9.00 0.00 10.00 0.00 13.302 12.6501
21 4 9.00 0.00 8.00 0.00 10.00 0.00 11.00 0.00 13.307 12.6990
22 4 10.00 0.00 9.00 0.00 11.00 0.00 12.00 0.00 13.317 12.7835
23 4 11.00 0.00 10.00 0.00 12.00 0.00 13.00 0.00 13.336 12.9266
24 4 12.00 0.00 11.00 0.00 13.00 0.00 14.00 0.00 13.375 13.1871
25 4 13.00 0.00 12.00 0.00 14.00 0.00 15.00 0.00 13.458 13.7017
26 4 14.00 0.00 13.00 0.00 15.00 0.00 16.00 0.00 13.665 14.8151
27 4 15.00 0.00 14.00 0.00 16.00 0.00 17.00 0.00 14.107 16.9138
28 4 16.00 0.00 15.00 0.00 17.00 0.00 18.00 0.00 12.544 9.5202
29 4 17.00 0.00 16.00 0.00 18.00 0.00 19.00 0.00 10.183 -1.7850
30 4 18.00 0.00 17.00 0.00 19.00 0.00 20.00 0.00 9.640 -2.2646
31 4 19.00 0.00 18.00 0.00 20.00 0.00 21.00 0.00 9.881 -1.0075
32 4 20.00 0.00 19.00 0.00 21.00 0.00 22.00 0.00 10.011 -0.8956
33 4 21.00 0.00 20.00 0.00 22.00 0.00 23.00 0.00 10.181 -1.8721
34 4 22.00 0.00 21.00 0.00 23.00 0.00 24.00 0.00 10.565 -4.4820
35 4 23.00 0.00 22.00 0.00 24.00 0.00 25.00 0.00 8.331 15.1685

```

The .dat file – Pole-pole and pole-dipole arrays

If the location of the remote electrode(s) for pole-pole and pole-dipole configurations aren't specified the program assumes the conditions for an ideal pole-pole or pole-dipole array is met.

```

1 Pole-pole survey with remote electrodes not specified
2 1.00000
3 11
4 2
5 Type of measurement (0=app. resistivity,1=resistance)
6 0
7 295
8 2
9 0
10 2 0.00000 0.00000 1.00000 0.00000 9.71588
11 2 1.00000 0.00000 2.00000 0.00000 9.77284
12 2 2.00000 0.00000 3.00000 0.00000 9.82908
13 2 3.00000 0.00000 4.00000 0.00000 9.91349
14 2 4.00000 0.00000 5.00000 0.00000 10.04541
15 2 5.00000 0.00000 6.00000 0.00000 10.27310
16 2 6.00000 0.00000 7.00000 0.00000 10.72195
17 2 7.00000 0.00000 8.00000 0.00000 11.68144
18 2 8.00000 0.00000 9.00000 0.00000 13.53788
19 2 9.00000 0.00000 10.00000 0.00000 15.54942
20 2 10.00000 0.00000 11.00000 0.00000 16.61592
21 2 11.00000 0.00000 12.00000 0.00000 16.94865
22 2 12.00000 0.00000 13.00000 0.00000 16.68214
23 2 13.00000 0.00000 14.00000 0.00000 15.68086
24 2 14.00000 0.00000 15.00000 0.00000 13.75145
25 2 15.00000 0.00000 16.00000 0.00000 12.01413
26 2 16.00000 0.00000 17.00000 0.00000 11.24185
27 2 17.00000 0.00000 18.00000 0.00000 11.21267
28 2 18.00000 0.00000 19.00000 0.00000 12.14866

```

```

1 Pole-pole survey with remote electrodes specified
2 1.00000
3 11
4 2
5 Type of measurement (0=app. resistivity,1=resistance)
6 0
7 Remote electrodes specified Header for remote electrode specification
8 C2 far electrode X and Y location
9 -25.000,10.000,0.000
10 P2 far electrode X and Y location
11 60.000,0.000,0.000
12 Exact geometric factor used Indication of geometric factor used
13 295
14 2
15 0
16 2 0.00000 0.00000 1.00000 0.00000 9.71588
17 2 1.00000 0.00000 2.00000 0.00000 9.77284
18 2 2.00000 0.00000 3.00000 0.00000 9.82908
19 2 3.00000 0.00000 4.00000 0.00000 9.91349
20 2 4.00000 0.00000 5.00000 0.00000 10.04541
21 2 5.00000 0.00000 6.00000 0.00000 10.27310
22 2 6.00000 0.00000 7.00000 0.00000 10.72195
23 2 7.00000 0.00000 8.00000 0.00000 11.68144
24 2 8.00000 0.00000 9.00000 0.00000 13.53788
25 2 9.00000 0.00000 10.00000 0.00000 15.54942
26 2 10.00000 0.00000 11.00000 0.00000 16.61592
27 2 11.00000 0.00000 12.00000 0.00000 16.94865
28 2 12.00000 0.00000 13.00000 0.00000 16.68214

```


The .dat file – topography – 2 options

In separate list:

```

355 4 56.00000 0 92.00000 0 68.00000 0 80.00000 0 1091.00000
356 4 58.00000 0 94.00000 0 70.00000 0 82.00000 0 1160.00000
357 4 60.00000 0 96.00000 0 72.00000 0 84.00000 0 1680.00000
358 Topography in separate list Header for topography
359 2 1 for true horizontal, 2 for surface distances
360 24 Number of topography points
361 -36,0.044
362 -34,0.134
363 -32,0.311
364 -30,0.503
365 -28,0.712
366 -26,1.161
367 -24,1.492
368 -22,1.833
369 -20,2.269
370 -18,2.578
371 -16,2.483
372 -14,2.714
373 -12,3.088
374 -10,3.443
375 -8,3.758
376 -6,3.924
377 -4,4.122
378 -2,4.306
379 0,4.526
380 2,4.747
381 4,5.028
382 6,5.104
383 8,5.111
384 10,5.138
385 1 Topography data point coinciding with first electrode
386 0 End of file

```

Last 3 data lines

Topography data: x-coordinates, elevation

In data lines, as z coordinates:

```

1 General array format with topography example
2 1.0
3 11
4 0
5 Type of measurement (0=app. resistivity,1=resistance)
6 0
7 407
8 1
9 0
10 4 0.00 1.78 3.00 1.68 1.00 1.93 2.00 1.89 10.158
11 4 1.00 1.93 4.00 1.32 2.00 1.89 3.00 1.68 10.168
12 4 2.00 1.89 5.00 1.32 3.00 1.68 4.00 1.32 10.184
13 4 3.00 1.68 6.00 0.31 4.00 1.32 5.00 1.32 10.225
14 4 4.00 1.32 7.00 0.48 5.00 1.32 6.00 0.31 10.337
15 4 5.00 1.32 8.00 0.83 6.00 0.31 7.00 0.48 10.708
16 4 6.00 0.31 9.00 1.31 7.00 0.48 8.00 0.83 11.668
17 4 7.00 0.48 10.00 1.78 8.00 0.83 9.00 1.31 12.542
18 4 8.00 0.83 11.00 1.93 9.00 1.31 10.00 1.78 12.871
19 4 9.00 1.31 12.00 1.89 10.00 1.78 11.00 1.93 13.238
20 4 10.00 1.78 13.00 1.68 11.00 1.93 12.00 1.89 13.342
21 4 11.00 1.93 14.00 1.32 12.00 1.89 13.00 1.68 13.231
22 4 12.00 1.89 15.00 1.32 13.00 1.68 14.00 1.32 12.855
23 4 13.00 1.68 16.00 0.31 14.00 1.32 15.00 1.32 12.511
24 4 14.00 1.32 17.00 0.48 15.00 1.32 16.00 0.31 11.598
25 4 15.00 1.32 18.00 0.83 16.00 0.31 17.00 0.48 10.471
26 4 16.00 0.31 19.00 1.31 17.00 0.48 18.00 0.83 9.203
27 4 17.00 1.31 20.00 1.78 18.00 0.83 19.00 1.31 8.368

```

The .dat file – global coordinates

```

794 4      235.00      4.82      355.00      7.41      305.00      8.33      315.00      8.44      138.0700
795 4      235.00      4.82      355.00      7.41      315.00      8.44      325.00      8.28      134.3600
796 4      235.00      4.82      355.00      7.41      325.00      8.28      335.00      8.00      138.9900
797 4      235.00      4.82      355.00      7.41      335.00      8.00      345.00      7.72      138.6200
798 0
799 Global Coordinates present
800 Number of coordinate points
801 17
802 Local Longitude Latitude
803 85.00 572088.12 6222426.57
804 90.00 572088.28 6222421.58
805 110.00 572088.91 6222401.60
806 115.00 572089.07 6222396.61
807 120.00 572089.23 6222391.62
808 125.00 572089.39 6222386.66
809 160.00 572090.50 6222351.66
810 165.00 572090.66 6222346.67
811 170.00 572090.82 6222341.68
812 175.00 572090.98 6222336.68
813 200.00 572091.77 6222311.72
814 205.00 572091.93 6222306.74
815 250.00 572093.36 6222261.85
816 255.00 572093.52 6222256.88
817 260.00 572093.67 6222251.91
818 325.00 572098.11 6222187.28
819 355.00 572100.26 6222157.44
820 0

```

Last 4 data lines, or topography section
 Header lines
 Number of coordinate points
 Header line
 X-coordinate along profile, Longitude/UTMX, Latitude/UTMY
 End of file

Note: topography information must always come before global coordinates, coordinates must be in meters!

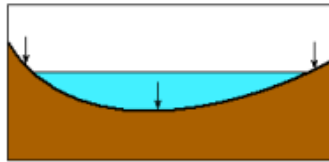
The .dat file – surveys in water – several options

Several options:

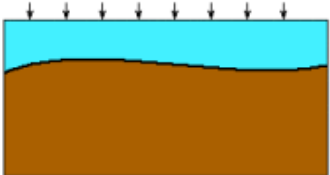
Case 1 : All electrodes underwater on bottom



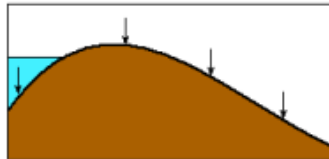
Case 2 : Some electrodes underwater and on land



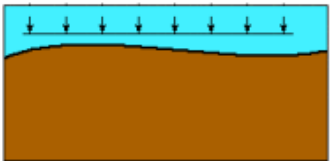
Case 3 : Electrodes floating on water surface



Case 4 : Electrodes on surface with limited water cover



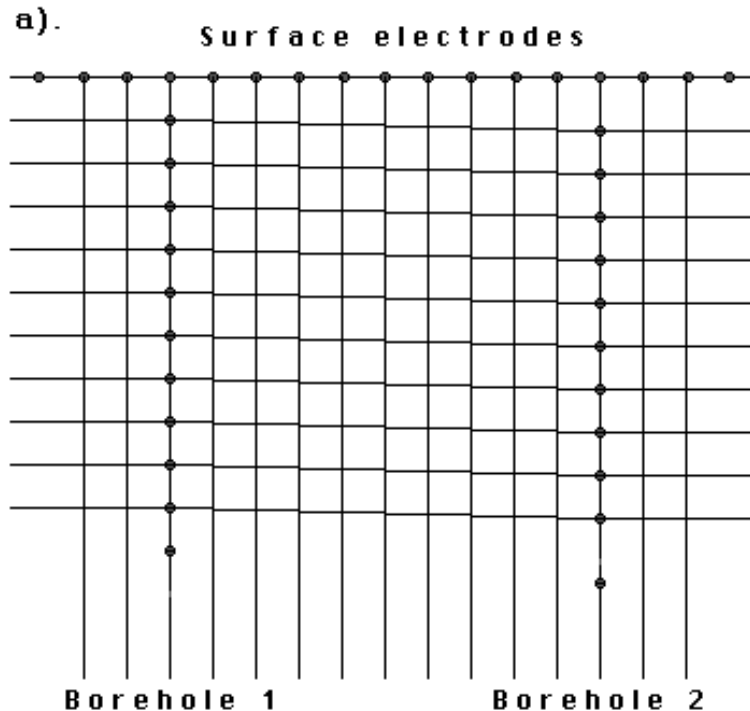
Case 5 : Electrodes suspended in water layer



See manual and file examples for specific formats, or ask.

- The water layer can be modelled
- Resistivity must be known
- Big impact on inversion result, especially for saline water

The .dat file – cross borehole and buried electrodes

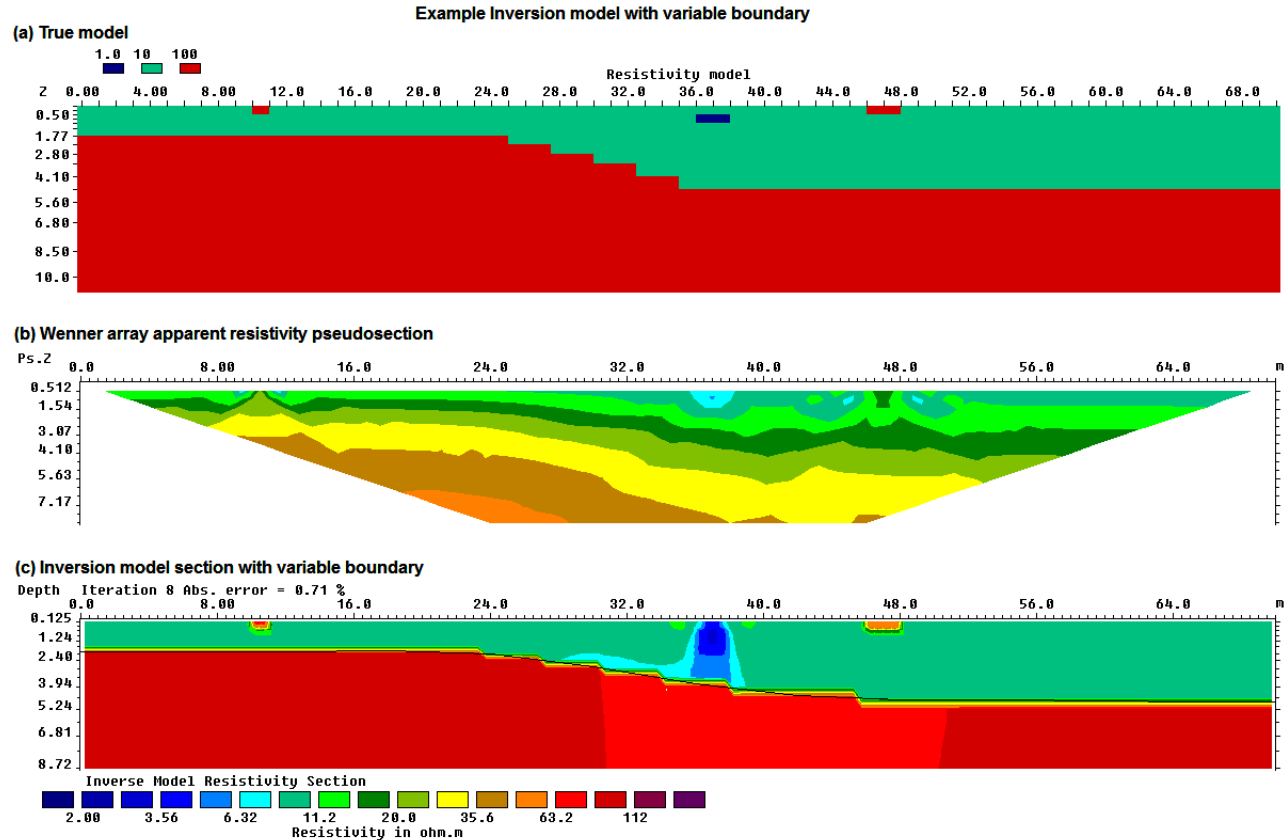


Data format specified in section 7.4 of the manual, please note:

- All electrodes must be specified in beginning of file
- Consider using resistance values as apparent resistivity calculations are not universally agreed on
- Define dummy electrodes to fulfill format requirements
- Note that topography must be provided as the elevation of the surface electrodes
- Format of data lines is as usual, but electrode positions must be consistent

<i>BOREDIFF.DAT file</i>	<i>Comments</i>
Borehole electrodes at different depths	<i>Name of survey line</i>
1.0	<i>Unit electrode spacing</i>
12	<i>Array number 12 for cross-borehole survey</i>
840	<i>Number of data points</i>
2	<i>2 to indicate XZ location format is used</i>
0	<i>0 for no I.P.</i>
Surface Electrodes	<i>Header for surface electrodes</i>
16	<i>Number of surface electrodes</i>
0.0, 0.0	<i>x- and z-location of first surface electrode</i>
1.0, 0.0	<i>Location of second surface electrode</i>
..	<i>Note 0.0 z value for surface electrode</i>
..	<i>Similar format for other surface electrodes</i>
..	
15.0, 0.0	<i>Last surface electrode</i>
Number of boreholes	<i>Header</i>
2	<i>Two boreholes in this data set</i>
Borehole 1 Electrodes	<i>Header for first borehole</i>
10	<i>Number of electrodes in first borehole</i>
4.0, 1.0	<i>x- and z-location of first electrode</i>
4.0, 2.0	<i>x- and z-location of second electrode</i>
4.0, 3.0	<i>Note electrodes are listed from the topmost</i>
..	<i>below the surface downwards</i>
..	<i>Similar format for other borehole electrodes</i>
..	
4.0, 10.0	<i>Last electrode in first borehole</i>
Borehole 2 Electrodes	<i>Header for second borehole</i>
10	<i>Number of electrodes in second borehole</i>
11.0, 1.5	<i>x- and z-location of first electrode</i>
11.0 2.5	<i>x- and z-location of second electrode</i>
..	
..	<i>Similar format for other borehole electrodes</i>
11.0, 10.5	<i>Last electrode in second borehole</i>
Measured data	<i>Header for section with the measurements</i>
3 0.0 0.0 1.0 0.0 2.0 0.0 101.5718	<i>The format for each data point is :-</i>
3 0.0 0.0 2.0 0.0 3.0 0.0 99.5150	<i>Number of electrodes used in measurement,</i>
3 0.0 0.0 3.0 0.0 4.0 0.0 99.2303	<i>x- and z-location of C1, C2, P1, P2</i>
3 0.0 0.0 4.0 0.0 5.0 0.0 99.1325	<i>electrodes, apparent resistivity value.</i>
..	
..	<i>Same format for other data points</i>
...	
3 11.0 11.0 11.0 3.5 11.0 2.50 120.8297	<i>Last data point</i>
0,0,0,0	<i>End with a few zeros.</i>

The .dat file – known boundaries and fixed regions

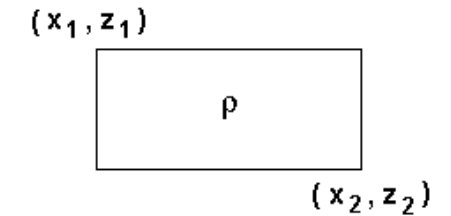


Fixing model resistivities

Data format

R
 x_1, z_1
 x_2, z_2
 ρ
 2.0

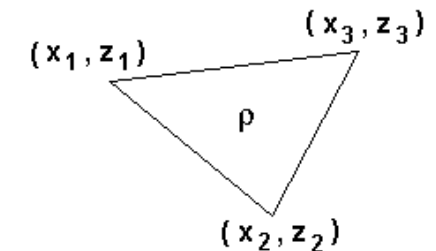
Rectangular regions



Data format

T
 x_1, z_1
 x_2, z_2
 x_3, z_3
 ρ
 2.0

Triangular regions



The .dat file – known boundaries and fixed regions

It is possible to specify the resistivity of known regions of the subsurface:

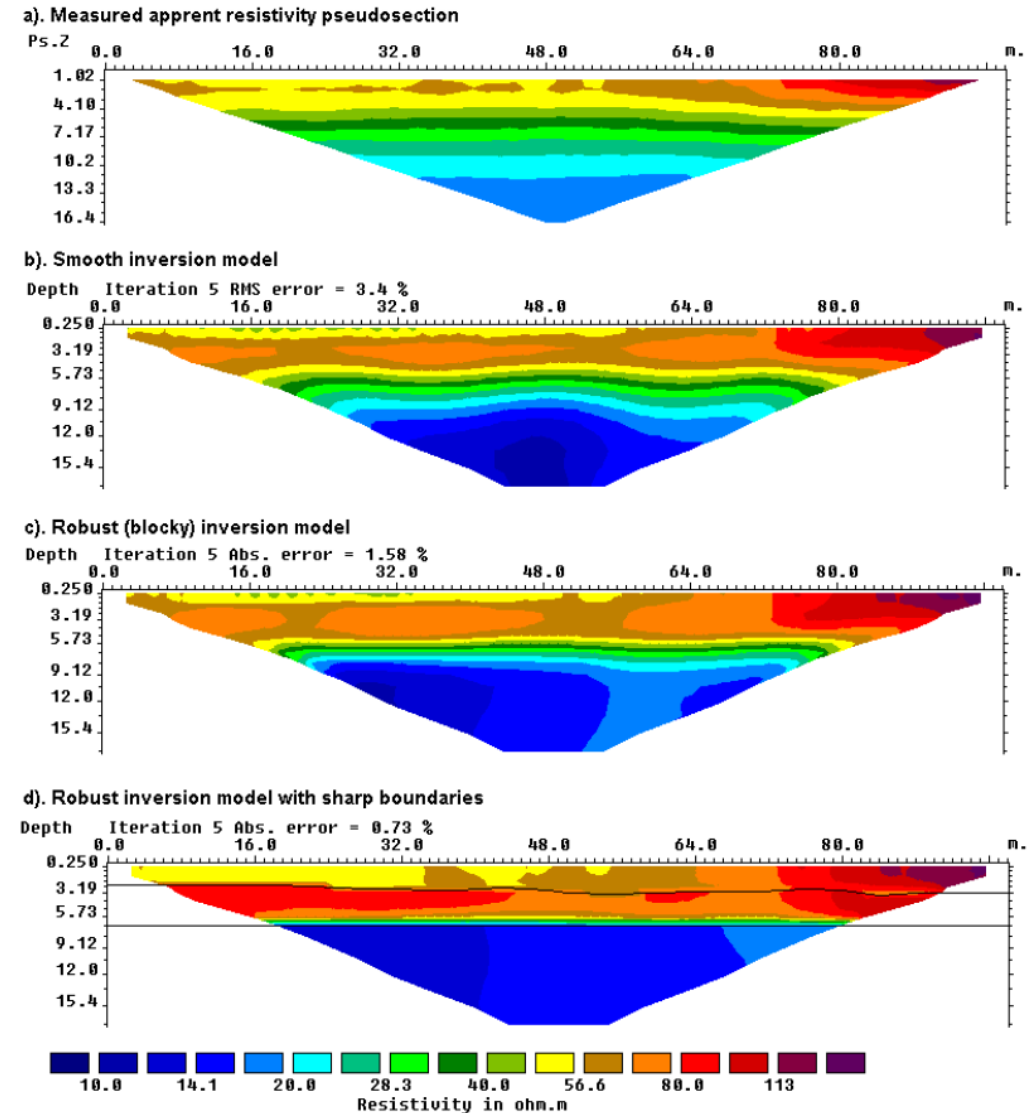
249	4	5.00000	0.00000	35.00000	0.00000	15.00000	0.00000	25.00000	
250	4	6.00000	0.00000	36.00000	0.00000	16.00000	0.00000	26.00000	
251	4	7.00000	0.00000	37.00000	0.00000	17.00000	0.00000	27.00000	
252	4	8.00000	0.00000	38.00000	0.00000	18.00000	0.00000	28.00000	
253	4	9.00000	0.00000	39.00000	0.00000	19.00000	0.00000	29.00000	
254	4	10.00000	0.00000	40.00000	0.00000	20.00000	0.00000	30.00000	
255	0	Topography information (none in this case)							
256	2	Number of fixed regions							
257	R	Shape of fixed region (R=rectangular, T=triangular)							
258		24.00000,	0.70000,	28.00000,	0.70000,	2.00000,	2.00000	{ X and Z coordinates of upper left and lower right corner of rectangle, resistivity value, damping factor	
259	T	Shape of fixed region (R=rectangular, T=triangular)							
260		30.00000,	0.00000,	30.00000,	3.00000,	45.00000,	3.00000,	10.00000,	{ X and Z coordinates of all 3 corners of triangle, resistivity value, damping factor
261	0	End all files wit a zero							

The damping factor controls how much the resistivity can vary during the inversion, 1.0 means that the resistivity can vary normally during the inversion, typical values range between 1.5 and 2.5, a high value e.g. 100 means that the resistivity of the region is completely fixed during inversion

The .dat file – known boundaries and fixed regions

It is possible to specify the depth to a known layer boundary e.g. from a seismic survey, even though the resistivities of the layers are unknown.

The format is very similar to the topography format, see section 7.10 of the manual



Hands on #2 – running an unsatisfactory inversion

1. Open Res2DInv
2. Load “GRUNDF1.dat” select “OK” in all popups and run inversion with standard settings

Troubleshooting an unsatisfactory inversion

1. **Removal of bad data points**
2. **Inversion method**
3. **Model discretization**
4. **Damping/smoothing settings**

Processing / removal of outliers – pre inversion

1. Load a data file
2. Select 'Edit->Exterminate bad data points'
3. Click the datapoints to remove
4. Exit, save modified data, reload

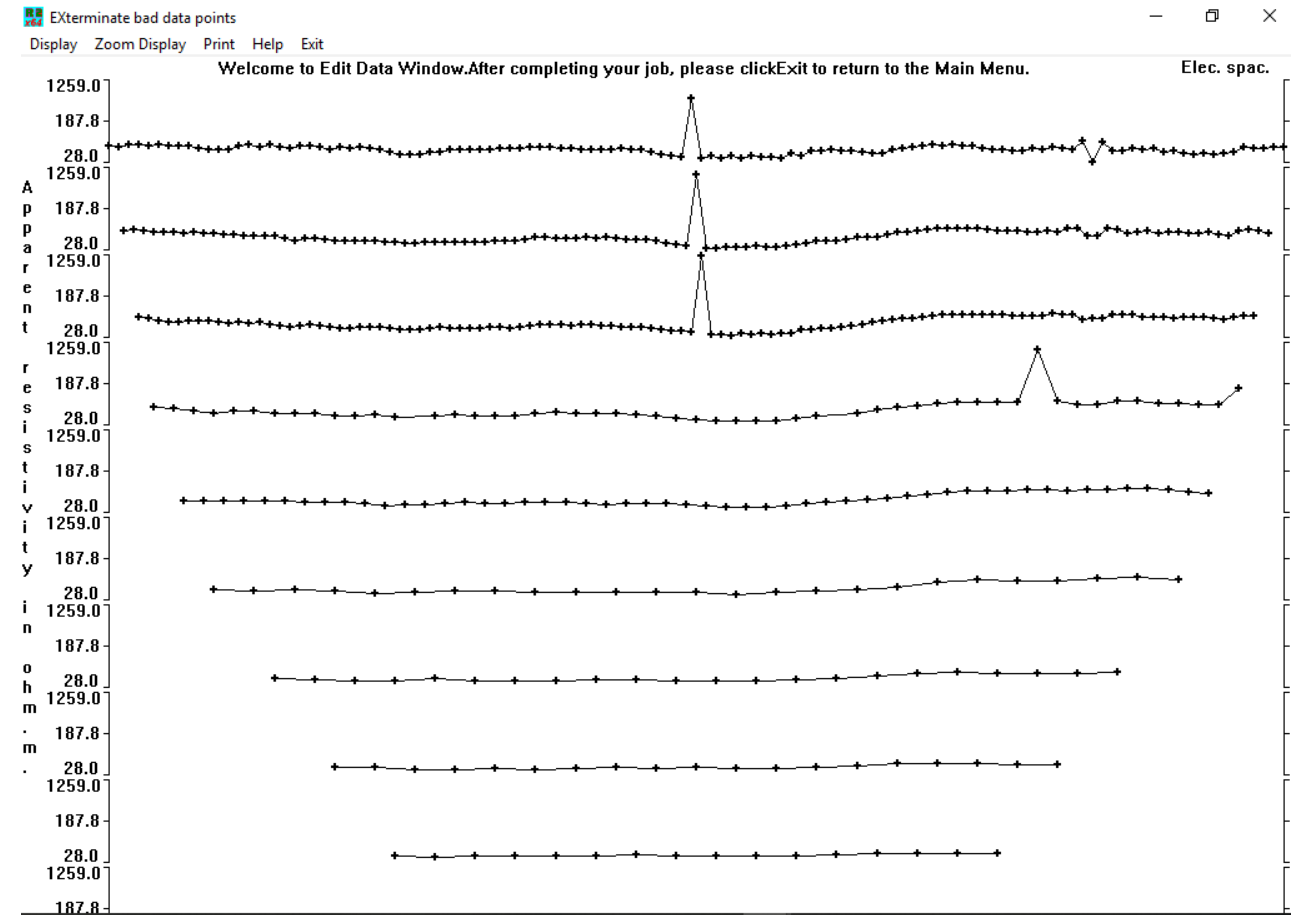
Function of keys to remove data points

To remove a data point, move the cursor to the point and click the left mouse button. To restore a point, click it again. The keys below will remove different sets of data points sharing a common electrode with the selected data point.

- A : Points using the present C1 electrode
- B : Points using the present C2 electrode
- C : Points using the present C1 or C2 electrode
- M : Points using the present P1 electrode
- N : Points using the present P2 electrode
- P : Points using the present P1 or P2 electrode
- L : All points in the data level is removed
- R : Restore all points in the data level

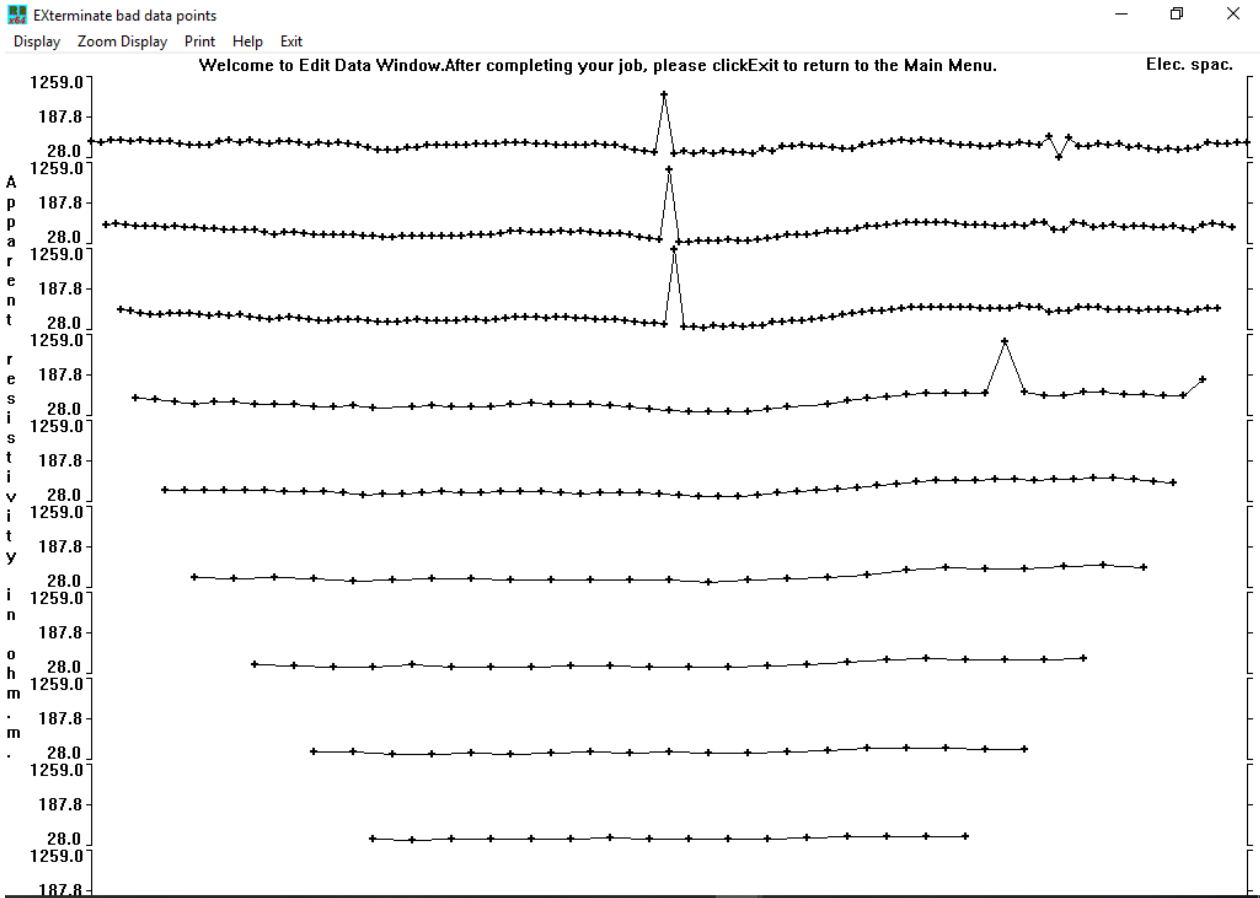
To remove a series of data points on the same profile, move the cursor to the left point and click the right mouse button. Next move the cursor to the right point and click the right mouse button.

OK

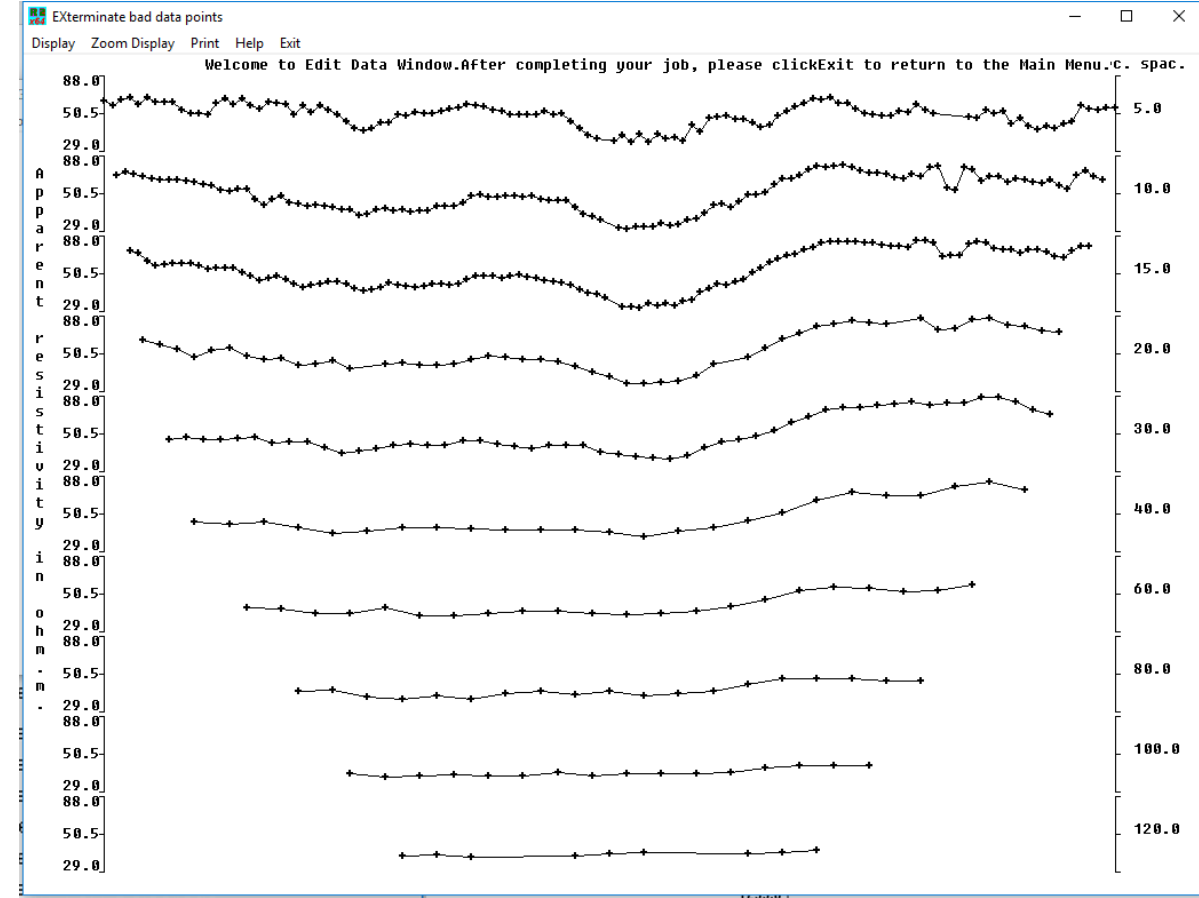


Processing / removal of outliers – simple example

Before:

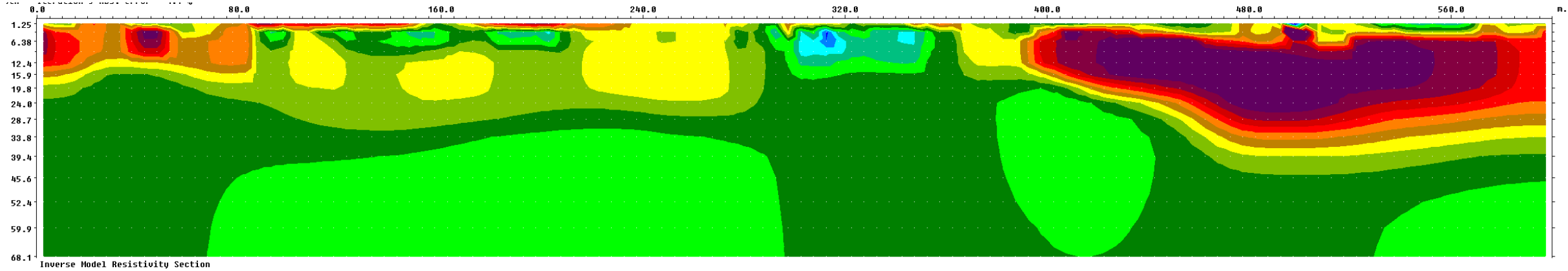


After:

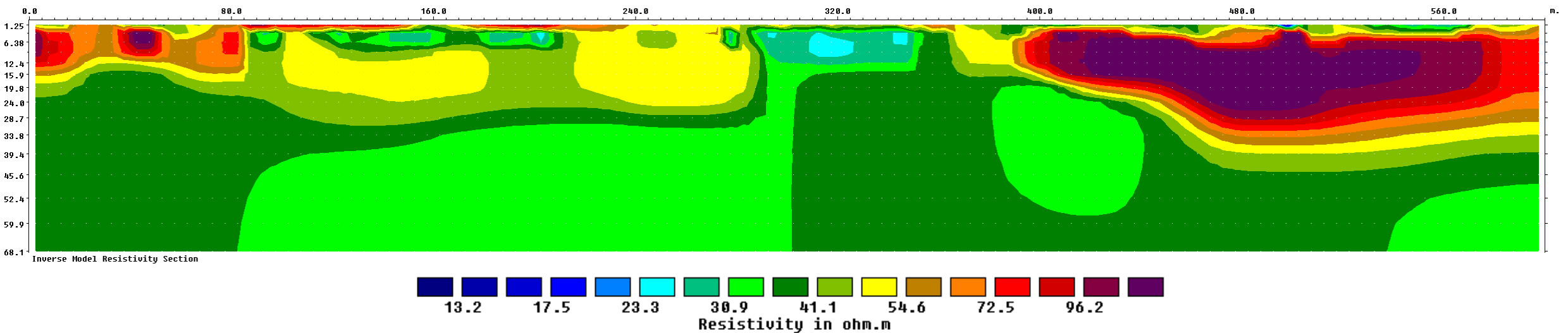


Processing / removal of outliers – simple example

Before:

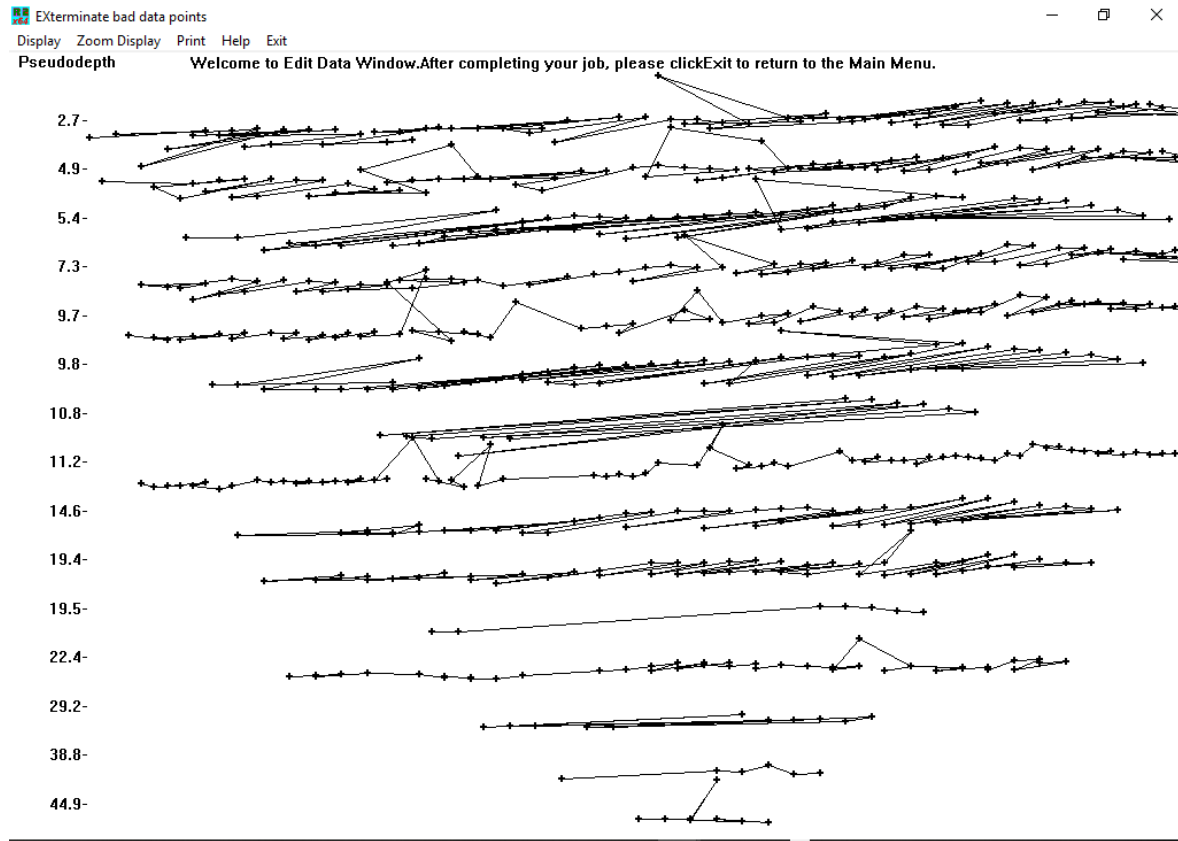


After:

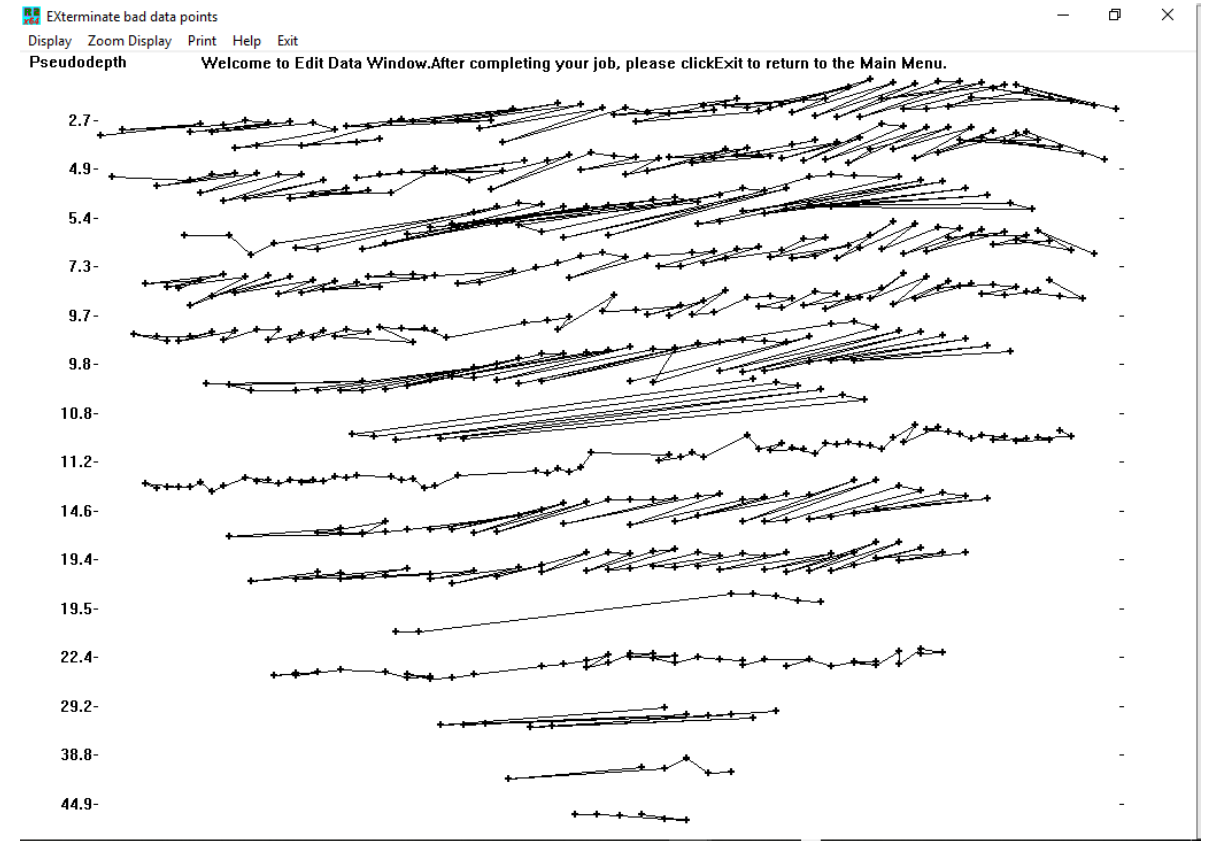


Processing / removal of outliers – Advanced example

Before:

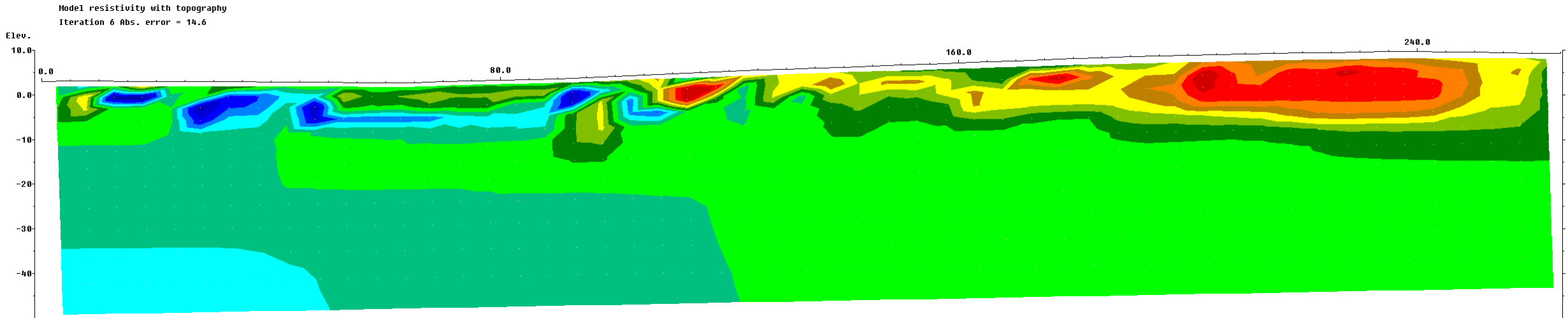


After:

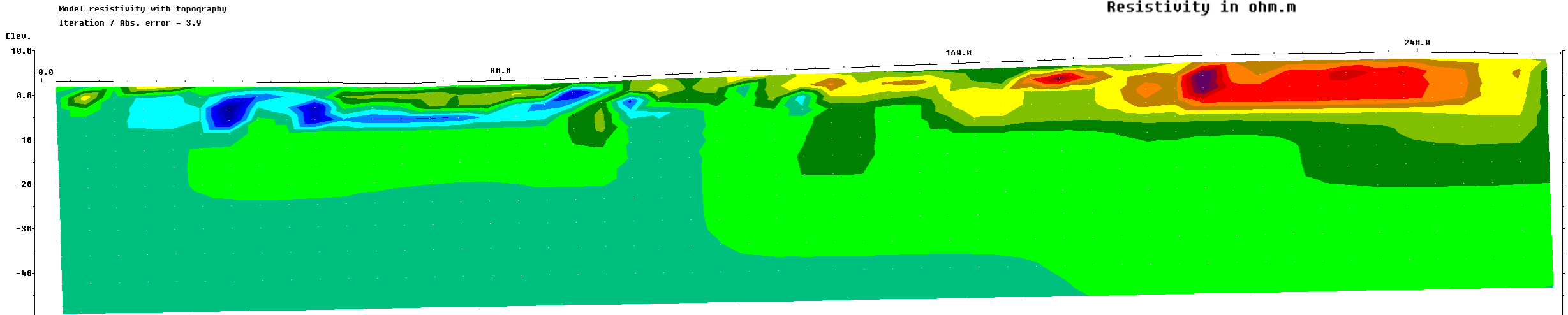


Processing / removal of outliers – Advanced example

Before:

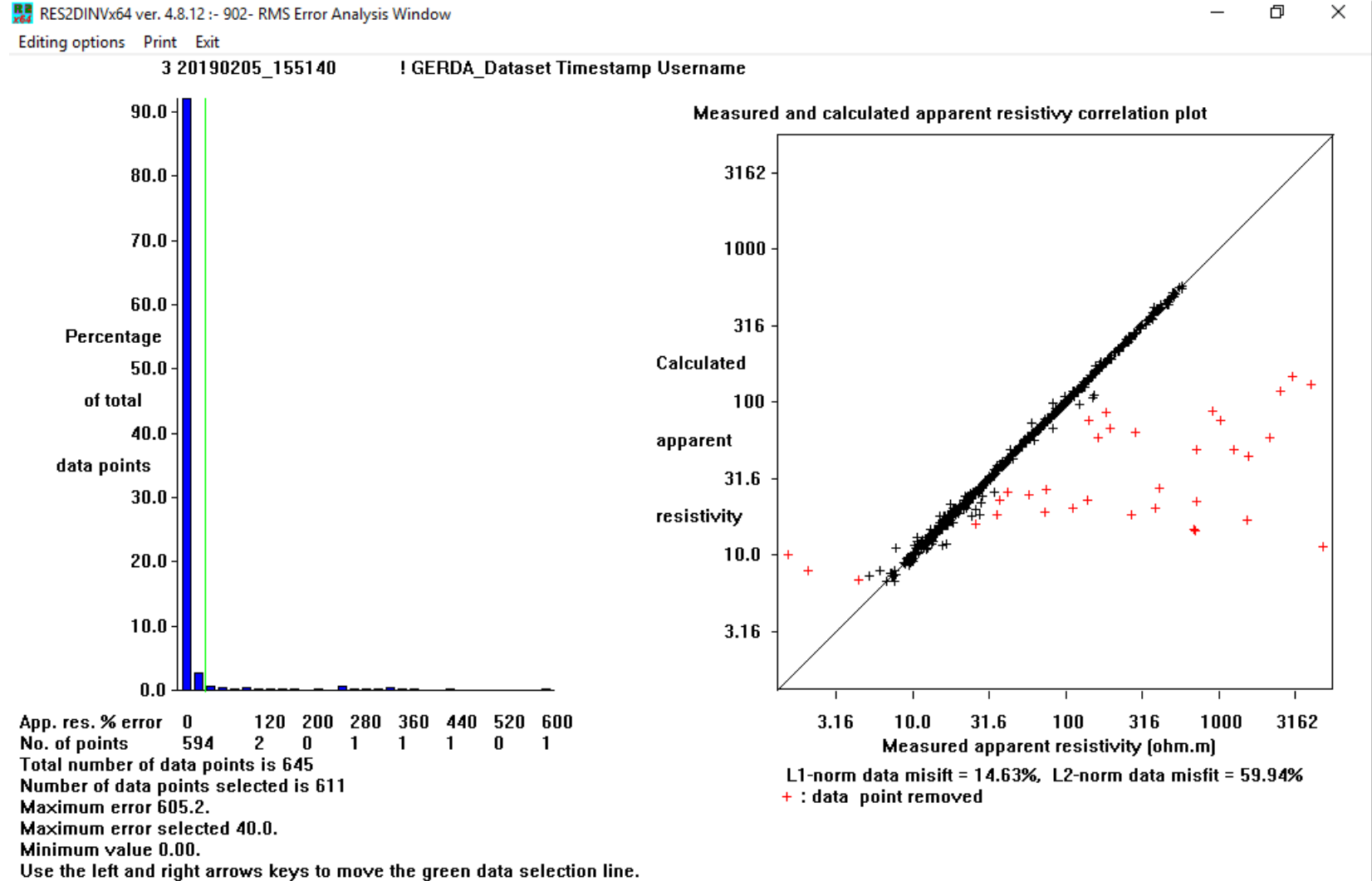


After:



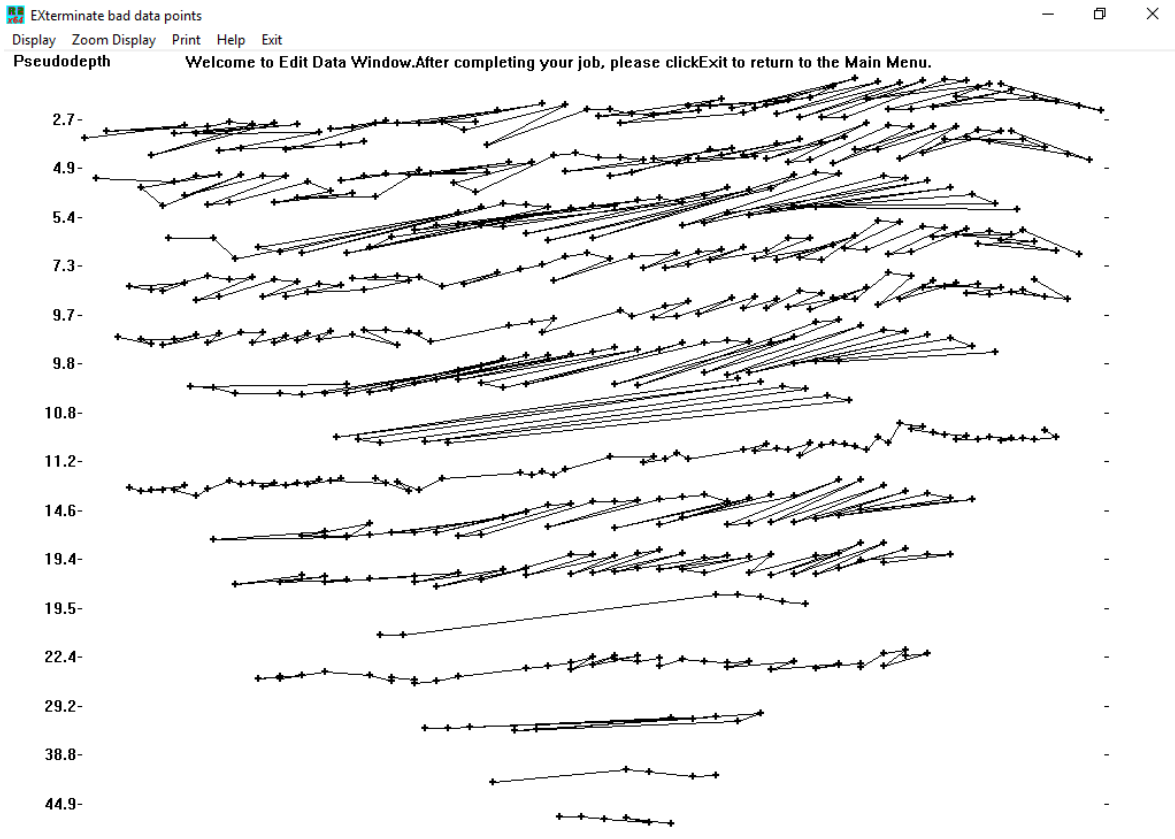
Processing / removal of outliers – statistical

1. Go to display mode and load .inv file after inversion
2. Select 'Edit data->RMS error statistics'
3. Select the datapoints to remove using arrow keys
4. Exit, save modified data, reload

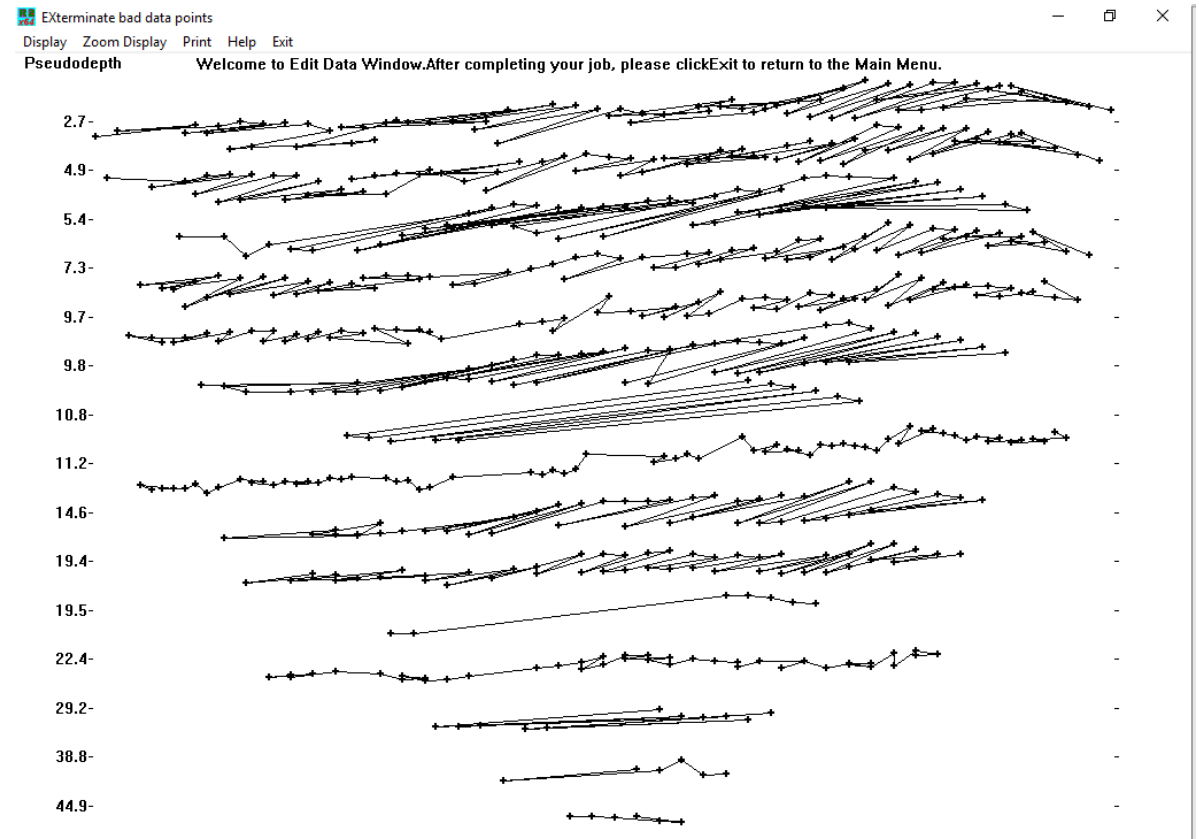


Processing / removal of outliers – statistical

Statistical:



Manual:



Processing / removal of outliers – statistical

Pitfalls of statistical processing:

- The removal of data points is solely based on how well they are fitted by the inversion
- By removing data points with a high misfit we are feeding the inversion “what it wants” and can create artificially good data fits
- That a datapoint isn't fitting doesn't necessarily mean that it is wrong, it can also be due to:
 1. The geology is too complicated to be described with the used inversion settings, or at all
 2. The dataset is so noisy that it is affecting the inversion
- In the worst case we are fitting the noise and throwing away good datapoints

Processing / removal of outliers – hands on

1. Load the datafile GRUNDF1.dat. Go to the 'Display' window, and then the 'Display data and model sections' option. The bad data points should be quite obvious.
2. leave the 'Display' window, choose 'Edit data' on the top menu bar followed by the 'Exterminate bad data points' option. Pick out the bad data points. After that save the edited data in a file. Read in this edited data file, and then go back to the 'Display' window and check the pseudosection again.
3. Leave the 'Display' window, and then run an inversion of the data set using the 'Inversion' and then the 'Least-squares inversion' menu options.
4. After the inversion has finished, go the 'Display' window to take a look at the model. After that choose the 'Edit data' and then the 'RMS error statistics' options. Take a look at the bar chart. Is it possible to remove more bad data points?
5. Try running an inversion of the data set without first manually removing the bad data points. Then use the 'RMS error statistics' option to remove them. Does this get rid of the bad data points also?
6. Compare the inversion results before and after removing the bad data points.

Inversion settings – introduction

As mentioned earlier: The inversion result is ununique

- **The result is shaped by the inversion setup**
- **The inversion setup should reflect prior knowledge and assumptions about the geology**
 - **Inversion method**
 - **Damping parameters**
 - **Model discretization**
 - **Forward modelling methods**
 - **Stopping criteria**

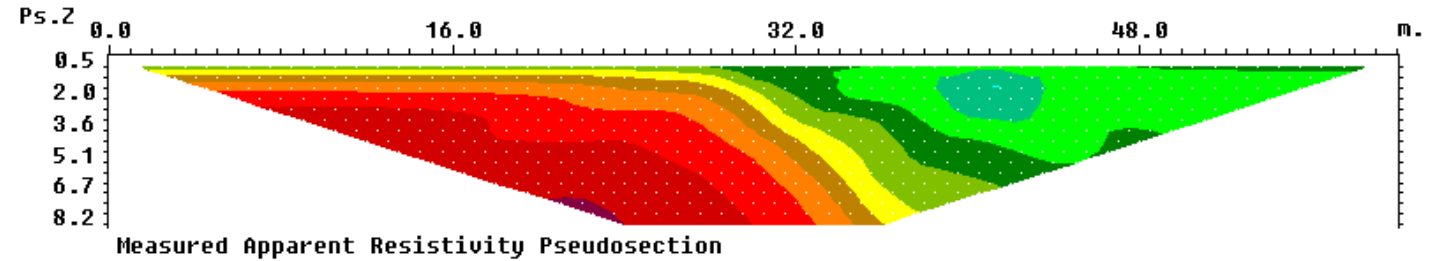
Inversion settings – Inversion method

Smoothness constrained least square inversion

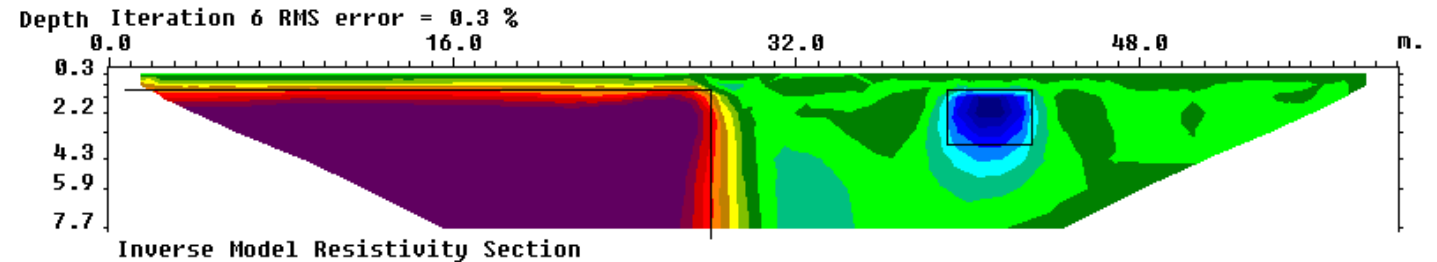
This formulation constrains the *change* in the model resistivity values, to be smooth but does not guarantee that the resistivity values change in a smooth manner.

Additional Option – Direct smoothing of the model resistivities as well, resulting in a smooth model.

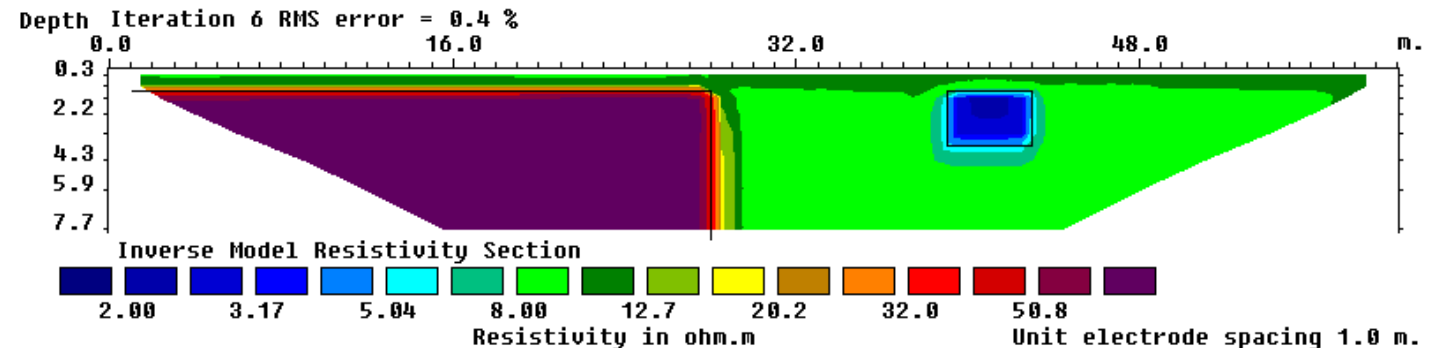
This is the standard inversion method used by Res2DInv!



b). Standard least-squares smoothness-constrain



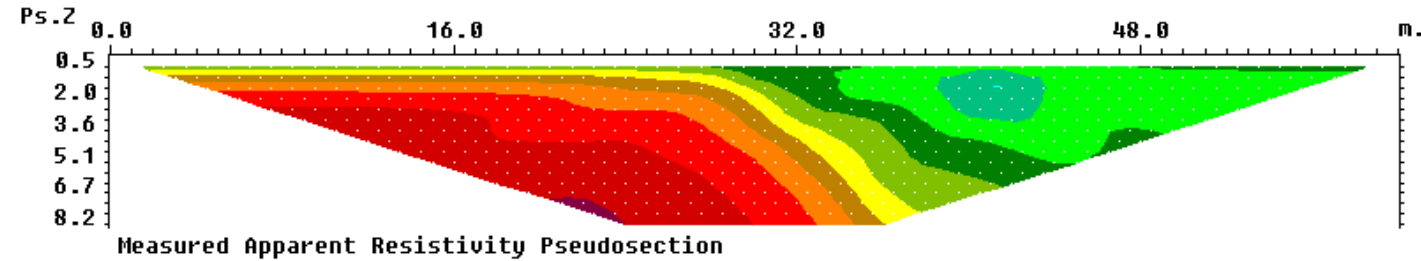
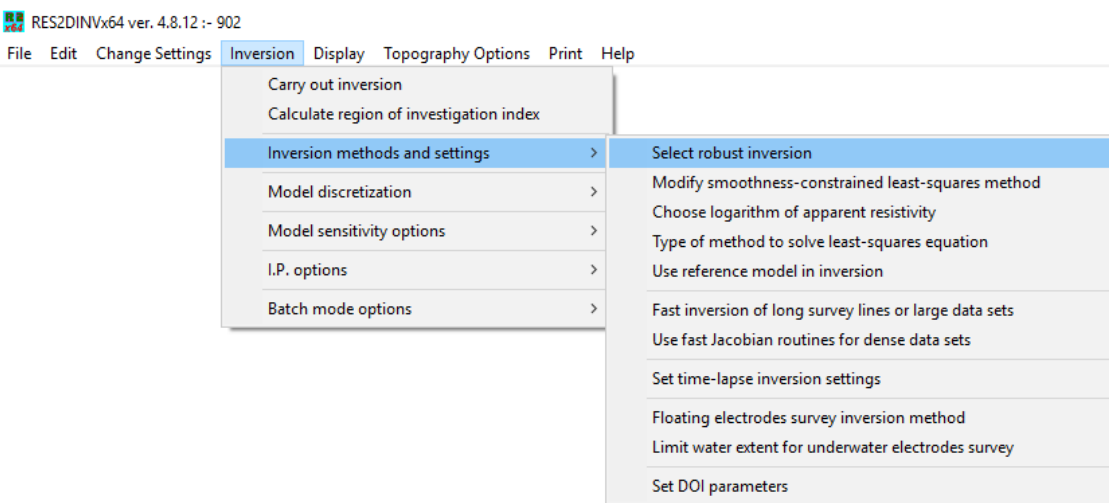
c). Robust inversion model constrain



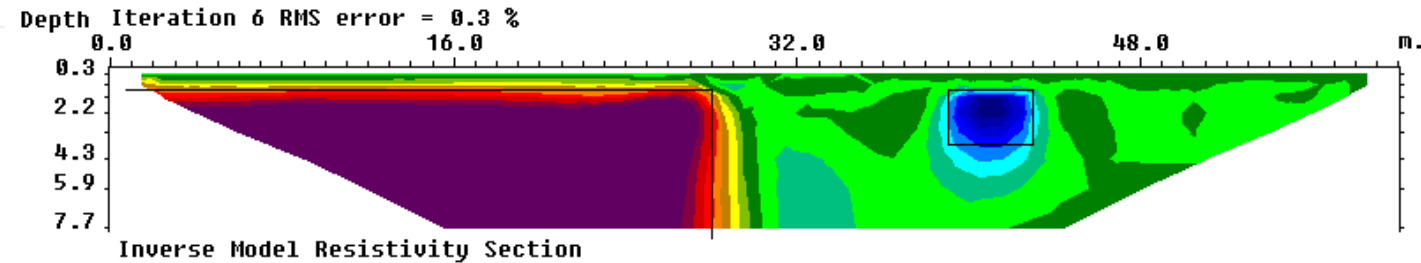
Inversion settings – Inversion method

Blocky (L1-norm) inversion

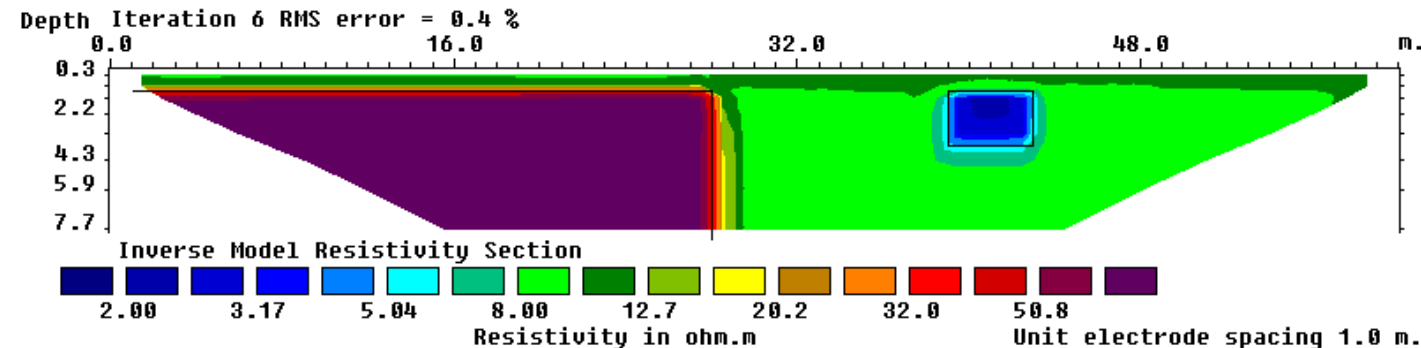
Favor models that are piecewise constant which is well suited for discrete geological variations



b). Standard least-squares smoothness-constrain



c). Robust inversion model constrain

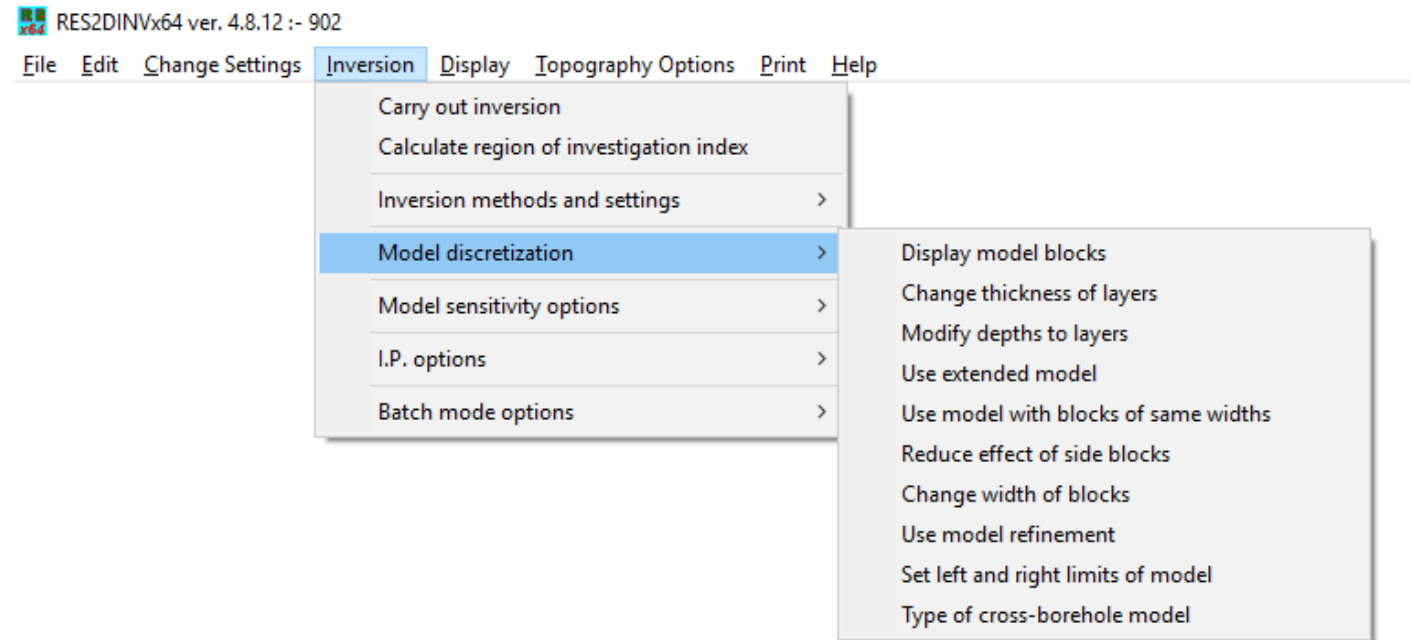


Vertical and horizontal model discretization

The standard discretization is fine in most cases

Reasons to change the discretization:

- **Slow inversion of large datasets**
- **Unsatisfactory data fit**
- **Artefacts in inversion results**
- **Special conditions or interests**



Inversion settings Filters / smoothing

RES2DINVx64 ver. 4.8.12 :- 902

File Edit **Change Settings** Inversion Display Topography Options Print Help

Inversion Damping Parameters >

Forward modeling method settings

Inversion Progress Settings >

Data/Display Selection >

Save inversion parameters

Read inversion parameters

Damping factors

Change of damping factor with depth

Limit range of model resistivity

Vertical/Horizontal flatness filter ratio

Use Diagonal Filter

Use L-Curve method to select damping factor

Limit range of data weights

Reduce variations near borehole

Use sensitivity values to damp variations near boreholes

Assessing the quality of an inversion

- **Depth of investigation (DOI)**
- **Model uncertainty**

Assessing the quality of an inversion – DOI

Is a measure of to which degree the inversion result is constrained by the measured data as opposed to the starting model.

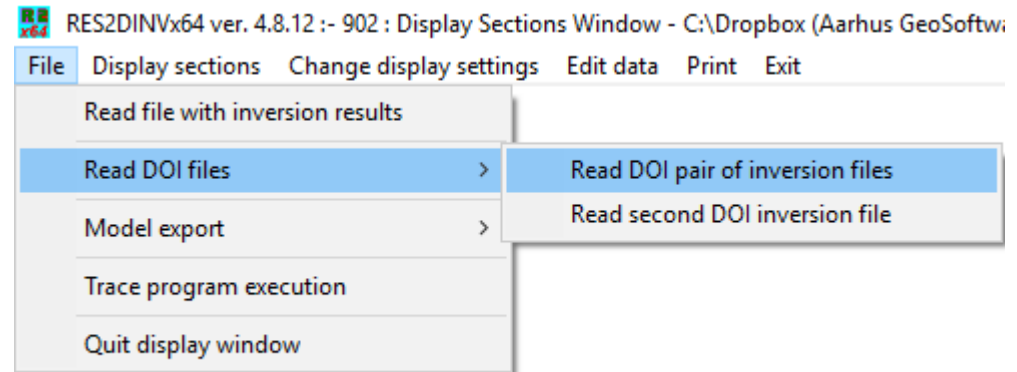
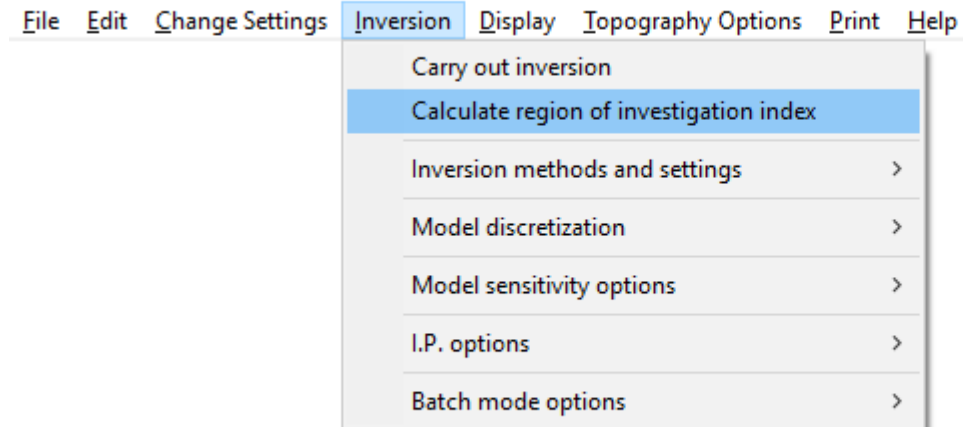
$$R(x, z) = \frac{q_1(x, z) - q_2(x, z)}{q_{m1} - q_{m2}}$$

Where q_{m1} and q_{m2} are the starting model resistivities, and $q_1(x,z)$ and $q_2(x,z)$ are the inversion results. Low value = data driven result, high value = constrain driven result.

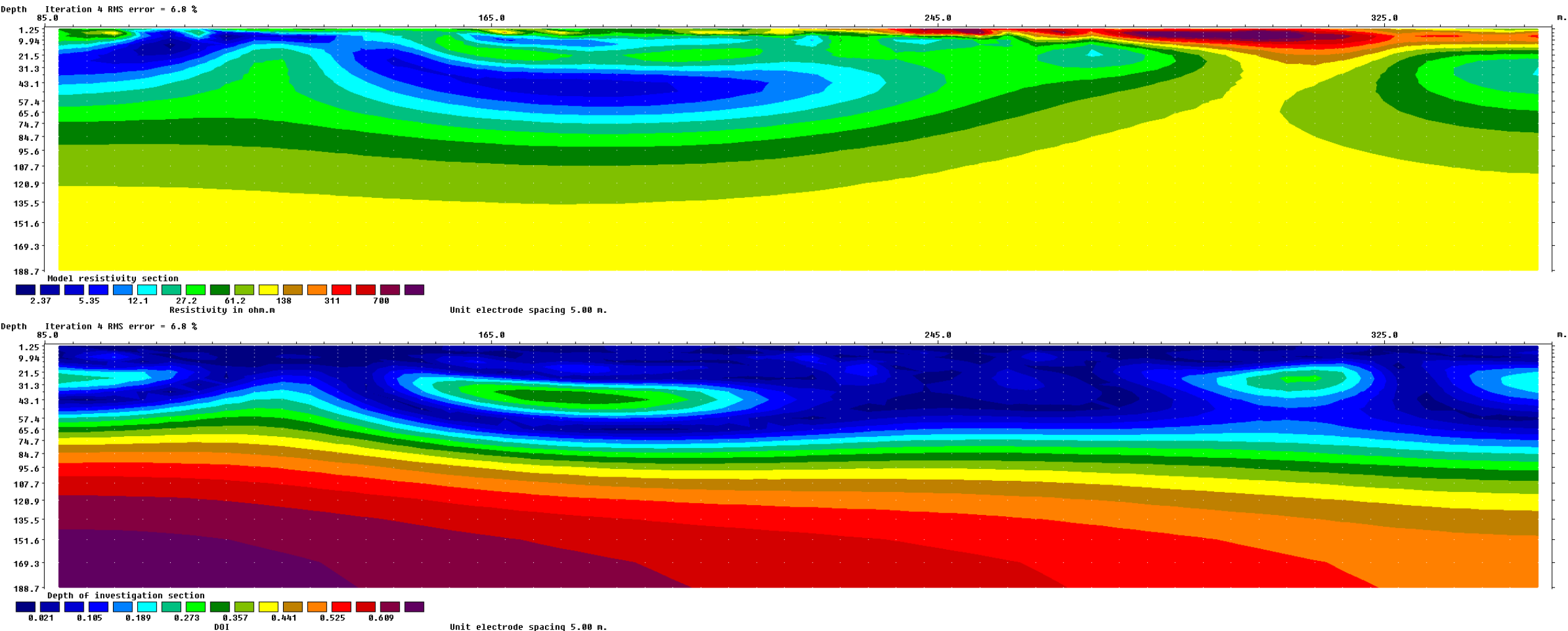
Assessing the quality of an inversion – DOI

Must be run and loaded as a separate inversion:

RES2DINVx64 ver. 4.8.12 :- 902 - C:\Dropbox (Aarhus GeoSoftware)\KV\tst\dat\DCIP\DAT for WB\Eskelund_02_indexd_topo_UTM.dat

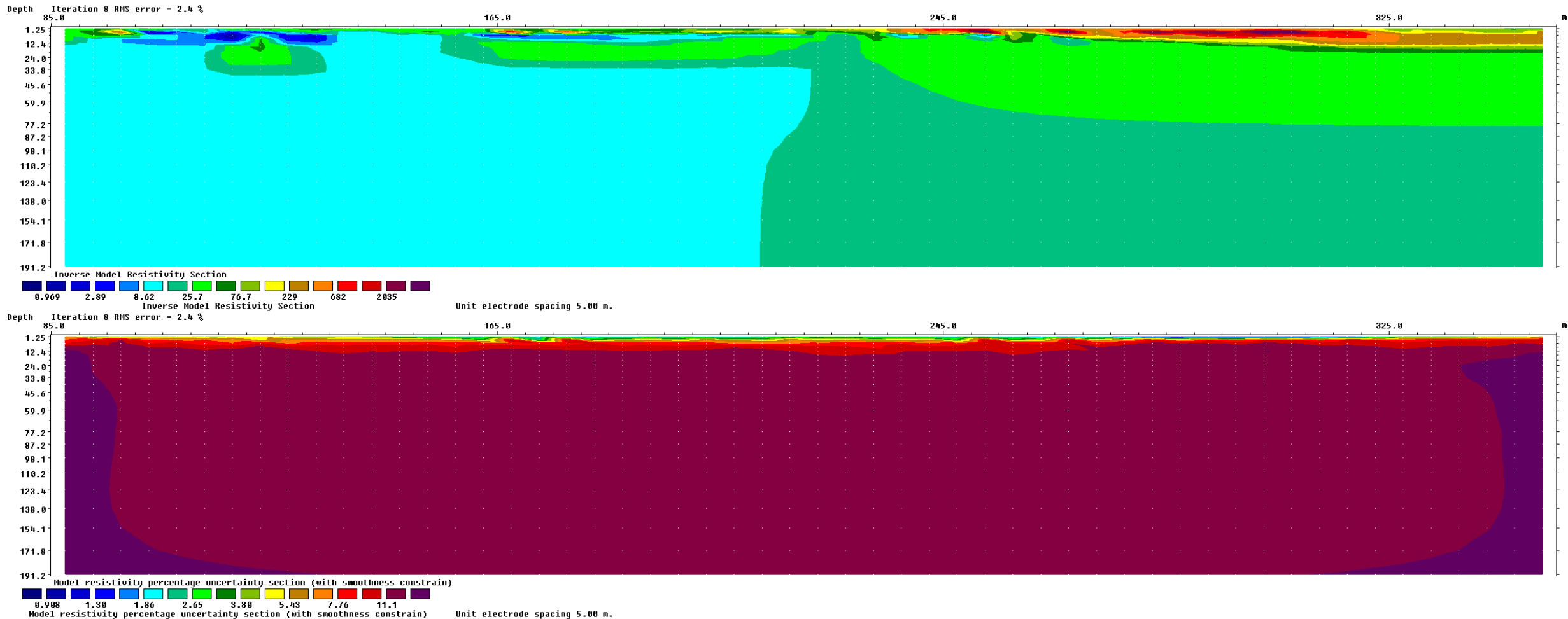


Assessing the quality of an inversion – DOI



Assessing the quality of an inversion – uncertainty

Not as precise as DOI, but doesn't require extra calculations



Inversion settings – hands on

1. Read in the data set GRUNDFOR.DAT and carry out the inversion with the default model discretization. You can take a look at the model discretization by selecting the 'Display model blocks' option.
2. choose the option to 'Allow number of model blocks to exceed data points', and run the inversion again. Make sure to use a different name for the inversion results file, for example GRUNFOR2.INV. Check out the arrangement of the cells again using the 'Display model blocks' option.
3. Now reduce the width of the side cells as well. Select the 'Make sure model blocks have same widths' option, and check out the arrangement of the cells. Next run the inversion again.

Compare the different inversions to see the effect of the model discretization on the inversion result.

Inversion settings – hands on

1. Read in the data set BLOCK_ONE.DAT and carry out the inversion with the default settings.
2. Next select the 'Select robust inversion' option, and enable both the robust model and data constrains. Run the inversion again, remember to use another name for the .inv file.

Compare the different inversions to see the effect of the inversion settings on the inversion result.

Try the option to display the inversion result as model blocks instead of contours to see the direct effect on the final model.

Inversion settings – hands on

1. Read in the data set ODARSLOV.DAT and carry out the inversion with the default settings.
2. Next change the inversion settings to robust inversion. Run the inversion again, remember to use another name for the .inv file.
3. Note the extreme resistivity values at the bottom-left and bottom-right corners can take. To reduce this effect, select the 'Reduce effect of side blocks' option, and then run the inversion again.

Compare the different inversions to see the effect of the different inversion settings on the inversion result.

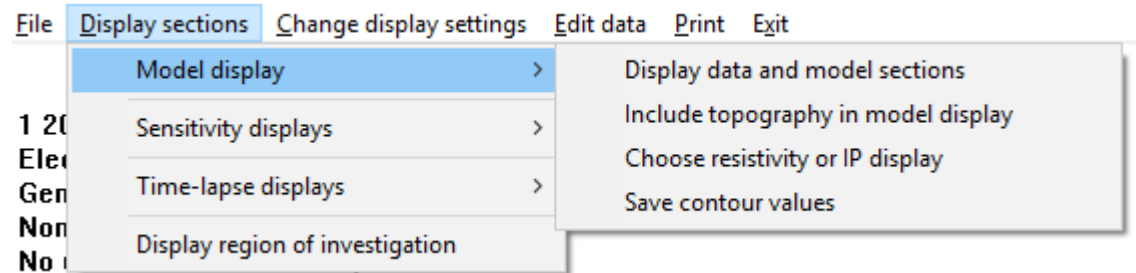
Again, try the option to display the inversion result as model blocks instead of contours to see the direct effect on the final model.

Visualization options

- **Build in visualization**
- **Exports for visualization in other software**

Visualization options – build in visualization – hands on

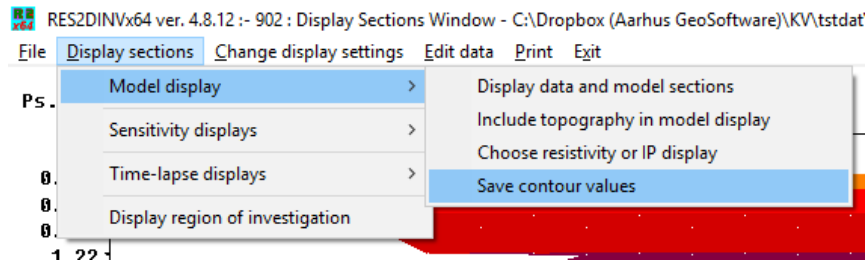
1. Enter display mode by selecting ‘Display-> Show inversion results’
2. If you have just run and inversion the result is automatically loaded, otherwise load it in using the file menu
3. Load rathcro.inv (use ipmodel.inv to test IP displays)
4. Test the different options in:



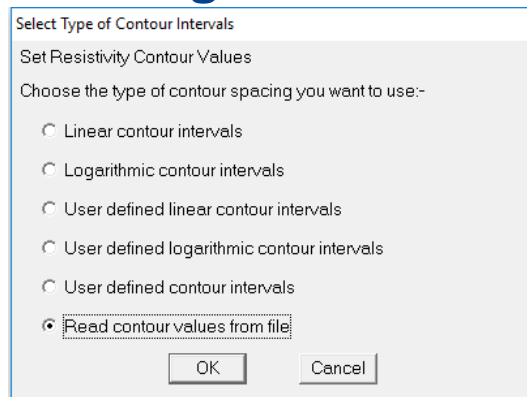
Visualization options – build in visualization – hands on

It is often useful to reuse the same color scale to compare results across profiles or inversions:

6. Saving a colorscale:

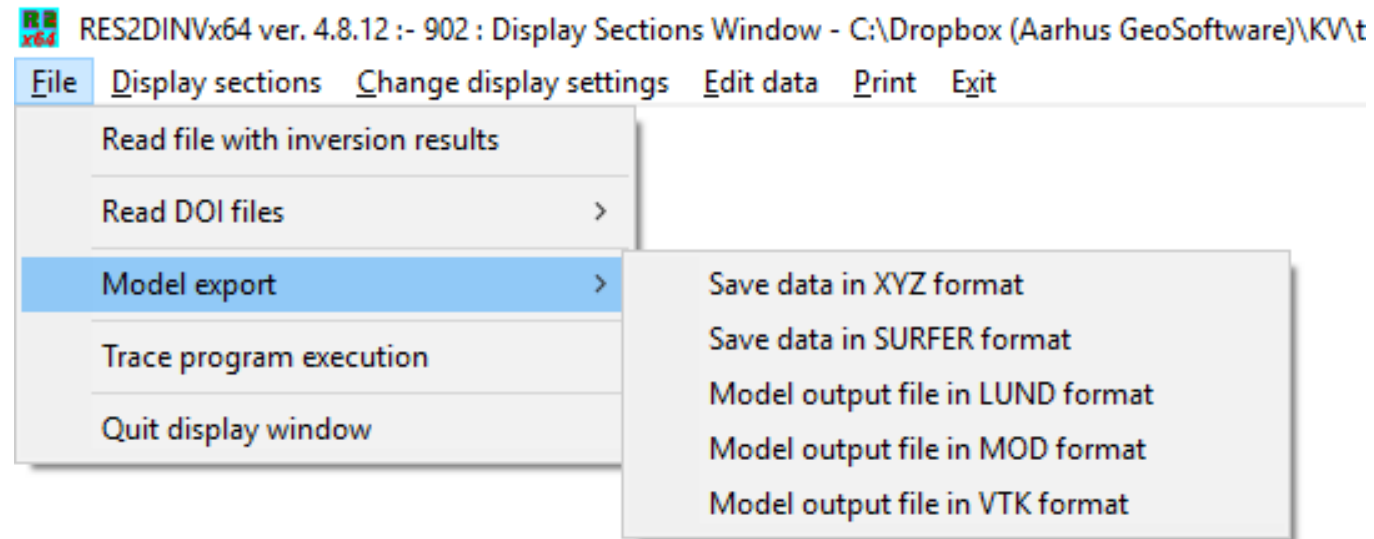


7. Loading a colorscale:



Visualization options - Exports

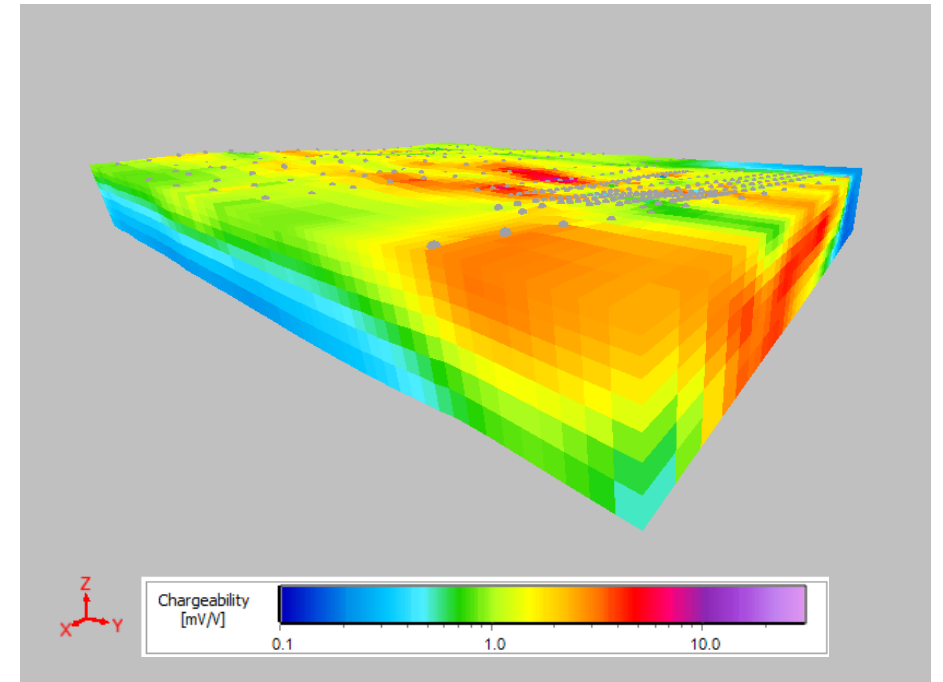
Res2DInv can export visualization results in a range of formats for use in visualization and modelling software:



After the break - Res3DInv

Res3DInv vs Res2DInv

- More complex than Res2DInv because everything is 3D
- Inversion settings and running inversions very similar
- Much more computationally demanding
- Data format is simpler in some ways and more complex in others



Model discretization

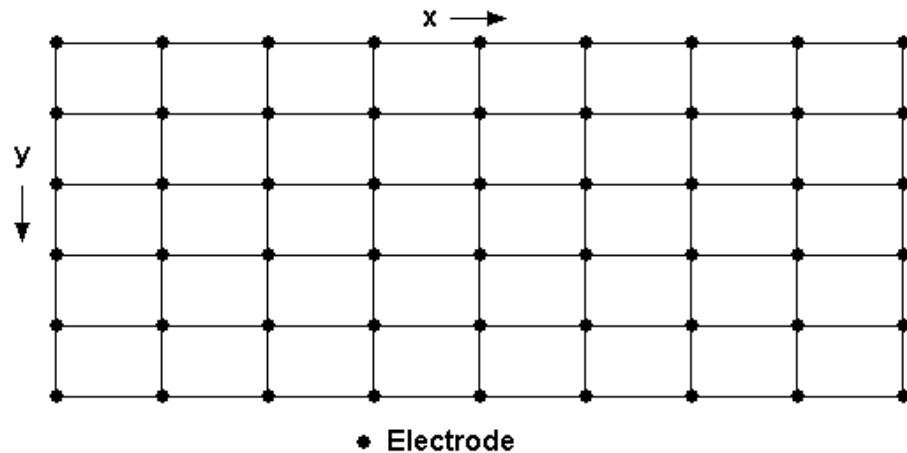
Because of the increased computational load of 3D inversion and the increased degrees of freedom much more care must be taken when defining the model discretization

- **For structured grids the x-y discretization is defined in the header**
- **For the arbitrary electrode locations format the x-y discretization is also defined in the header, but can also be edited from within the program**
- **Also remember to consider the number of layers and the thickness of those**
- **Rotating the grid can also decrease the size**

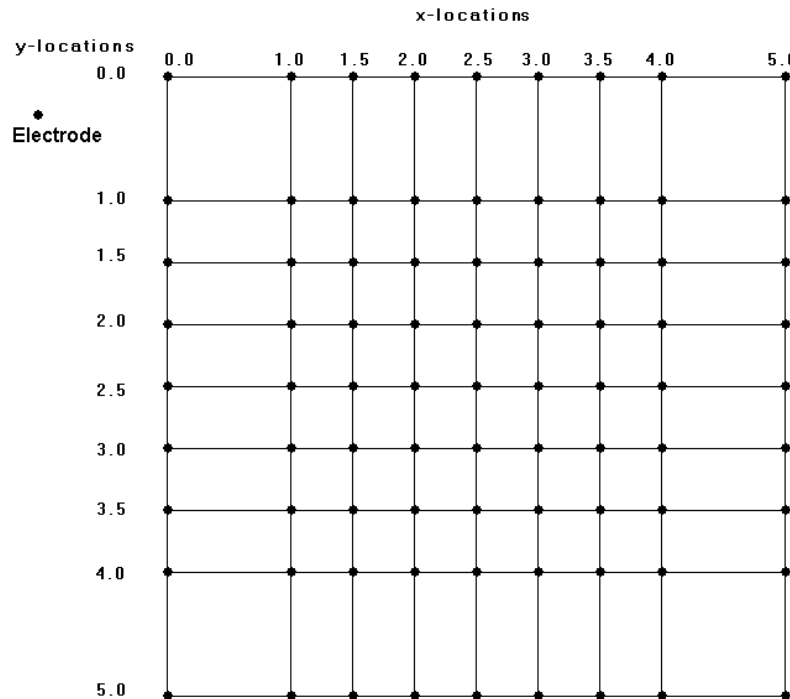
Res3DInv data format – survey grid and electrode locations

All the computational grid and electrode positions are specified at the beginning of the file, there are several options:

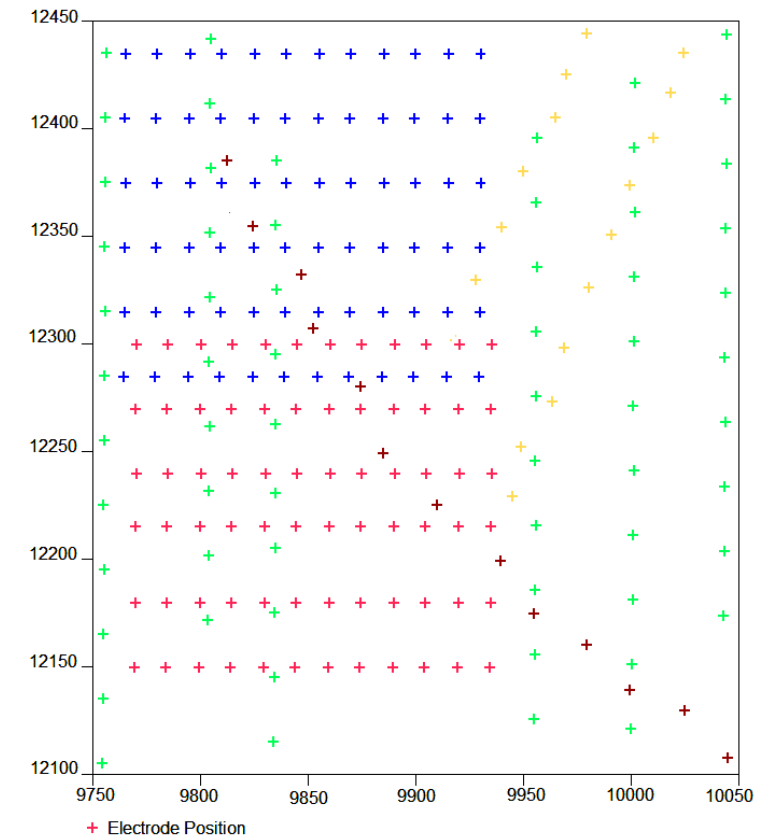
Uniform rectangular survey grid



Nonuniform rectangular survey grid



Arbitrary survey grid



Res3DInv data format – Uniform and nonuniform rectangular grid - header lines

All the computational grid and electrode positions are specified at the beginning of the file, there are several options:

Uniform rectangular survey grid

```
1 Uniform rectangular survey grid example
2 7      Number of electrodes in x-direction
3 7      Number of electrodes in y-direction
4 0.5    Unit electrode spacing in x-direction
5 0.5    Unit electrode spacing in y-direction
6 2      Array type (2 for pole-pole)
7 468    Number of data points
8 0.00    0.00    1.00 0.00    398.05
9 0.00    0.00    1.50 0.00    424.08
10 0.00    0.00    2.00 0.00    413.83
11 0.00    0.00    2.50 0.00    373.76
12 0.00    0.00    3.00 0.00    320.77
13 0.00    0.00    0.00 0.50    465.25
14 0.00    0.00    0.00 1.00    454.78
15 0.00    0.00    0.00 1.50    460.16
```

Nonuniform rectangular survey grid

```
1 Nonuniform rectangular survey grid example
2 9      Number of electrodes in x-direction
3 9      Number of electrodes in y-direction
4 Nonuniform grid Header indicating nonuniform grid
5 x-location of grid-lines
6 0.0 1.0 1.5 2.0 2.5 3.0 3.5 4.0 5.0
7 y-location of grid-lines
8 0.0 1.0 1.5 2.0 2.5 3.0 3.5 4.0 5.0
9 2      Array type (2 for pole-pole)
10 992    Number of data points
11 0.000    0.000    1.000    0.000    29.934
12 0.000    0.000    1.500    0.000    29.918
13 0.000    0.000    2.000    0.000    29.927
14 0.000    0.000    2.500    0.000    29.932
15 0.000    0.000    3.000    0.000    29.923
```

In these grids electrodes can only be located on the grid nodes

Res3DInv data format – arbitrary electrode position - header lines

```
1 3-D arbitrary electrodes data format
2 68,80 X and Y surface grid size
3 Nonuniform grid Header for non-uniform rectangular grid
4 x-location of grid-lines
5 571880.000 571885.000 571890.000 571895.000 571900.000 571905.000 571910.000 571915.000 571920.000 571925.000 X-location of all grid lines
6 571930.000 571935.000 571940.000 571945.000 571950.000 571955.000 571960.000 571965.000 571970.000 571975.000 (global coordinates)
7 571980.000 571985.000 571990.000 571995.000 572000.000 572005.000 572010.000 572015.000 572020.000 572025.000
8 572030.000 572035.000 572040.000 572045.000 572050.000 572055.000 572060.000 572065.000 572070.000 572075.000
9 572080.000 572085.000 572090.000 572095.000 572100.000 572105.000 572110.000 572115.000 572120.000 572125.000
10 572130.000 572135.000 572140.000 572145.000 572150.000 572155.000 572160.000 572165.000 572170.000 572175.000
11 572180.000 572185.000 572190.000 572195.000 572200.000 572205.000 572210.000 572215.000
12 y-location of grid-lines
13 6222155.000 6222160.000 6222165.000 6222170.000 6222175.000 6222180.000 6222185.000 6222190.000 6222195.000 6222200.000 Y-location of all grid lines
14 6222205.000 6222210.000 6222215.000 6222220.000 6222225.000 6222230.000 6222235.000 6222240.000 6222245.000 6222250.000 (global coordinates)
15 6222255.000 6222260.000 6222265.000 6222270.000 6222275.000 6222280.000 6222285.000 6222290.000 6222295.000 6222300.000
16 6222305.000 6222310.000 6222315.000 6222320.000 6222325.000 6222330.000 6222335.000 6222340.000 6222345.000 6222350.000
17 6222355.000 6222360.000 6222365.000 6222370.000 6222375.000 6222380.000 6222385.000 6222390.000 6222395.000 6222400.000
18 6222405.000 6222410.000 6222415.000 6222420.000 6222425.000 6222430.000 6222435.000 6222440.000 6222445.000 6222450.000
19 6222455.000 6222460.000 6222465.000 6222470.000 6222475.000 6222480.000 6222485.000 6222490.000 6222495.000 6222500.000
20 6222505.000 6222510.000 6222515.000 6222520.000 6222525.000 6222530.000 6222535.000 6222540.000 6222545.000 6222550.000
21 11 General array data format
22 0 No sub array type
23 Type of data (0=apparent resistivity,1=resistance) Data unit header
24 0 Apparent resistivity data
25 Point Electrodes outside grid present Header for arbitrary electrode positions
26 Number of point electrodes Header for number of arbitrary electrodes
27 334 Number of arbitrary electrodes
28 Compressed format used for point electrodes coordinates Header for "compressed format" this is usually used
29 1, 571884.9200, 6222499.4000, 1.6300 Electrode number, X-location, Y-location, Elevation (only electrodes not located on
30 2, 571889.8900, 6222498.9800, 1.6500 grid nodes need to be listed here.)
31 3, 571894.8700, 6222498.5600, 1.6700
32 4, 571899.8400, 6222498.1400, 1.6900
33 5, 571904.8200, 6222497.7300, 1.7000
34 6, 571905.4100, 6222545.3600, 1.6300
35 7, 571909.7900, 6222497.3100, 1.7200
36 8, 571909.8200, 6222543.0100, 1.6400
37 9, 571914.2300, 6222540.6600, 1.6600
```

Res3DInv data format – data lines

The data line format is the same for all grid types:

Pole-pole example with IP:

	C1-X	C1-Y	P1-X	P1-Y	A.Res.	I.P.
298	1.000	2.000	6.000	2.000	9.8064	-0.7452
299	1.000	2.000	7.000	2.000	9.7419	-1.4738
300	1.000	2.000	0.000	3.000	10.3088	2.1841
301	1.000	2.000	1.000	3.000	10.3778	2.6690
302	1.000	2.000	2.000	3.000	10.9918	6.7572
303	1.000	2.000	1.000	4.000	10.5644	4.1239
304	1.000	2.000	3.000	4.000	11.0035	9.2132
305	1.000	2.000	1.000	5.000	10.4259	3.3120
306	1.000	2.000	4.000	5.000	9.9305	1.7297
307	1.000	2.000	1.000	6.000	10.2240	1.8794
308	1.000	2.000	5.000	6.000	9.5697	-2.2696
309	1.000	2.000	1.000	7.000	10.0957	0.9139
310	1.000	2.000	6.000	7.000	9.6073	-2.4194
311	2.000	2.000	3.000	2.000	11.1181	7.9622
312	2.000	2.000	4.000	2.000	11.2147	9.7495
313	2.000	2.000	5.000	2.000	10.5308	5.5019
314	2.000	2.000	6.000	2.000	10.0787	1.7192
315	2.000	2.000	7.000	2.000	9.9123	0.1283
316	2.000	2.000	1.000	3.000	10.8094	5.5007
317	2.000	2.000	2.000	3.000	11.1181	7.9619
318	2.000	2.000	3.000	3.000	11.8588	14.6974

General/mixed array example, resistivity only:

	N.elec.	C1-X	C1-Y	C2-X	C2-Y	P1-X	P1-Y	P2-X	P2-Y	App.Res.
30	4	4.000	0.000	3.000	0.000	6.000	0.000	7.000	0.000	30.316
31	4	4.000	0.000	3.000	0.000	7.000	0.000	8.000	0.000	30.694
32	4	4.000	0.000	3.000	0.000	8.000	0.000	9.000	0.000	30.810
33	4	5.000	0.000	4.000	0.000	6.000	0.000	7.000	0.000	29.997
34	4	5.000	0.000	4.000	0.000	7.000	0.000	8.000	0.000	30.236
35	4	5.000	0.000	4.000	0.000	8.000	0.000	9.000	0.000	30.438
36	4	6.000	0.000	5.000	0.000	7.000	0.000	8.000	0.000	29.986
37	4	6.000	0.000	5.000	0.000	8.000	0.000	9.000	0.000	30.096
38	4	7.000	0.000	6.000	0.000	8.000	0.000	9.000	0.000	29.968
39	4	1.000	1.000	0.000	1.000	2.000	1.000	3.000	1.000	30.051
40	4	1.000	1.000	0.000	1.000	3.000	1.000	4.000	1.000	31.123
41	4	1.000	1.000	0.000	1.000	4.000	1.000	5.000	1.000	31.877
42	4	1.000	1.000	0.000	1.000	5.000	1.000	6.000	1.000	31.993
43	4	1.000	1.000	0.000	1.000	6.000	1.000	7.000	1.000	31.854
44	4	1.000	1.000	0.000	1.000	7.000	1.000	8.000	1.000	30.523
45	4	1.000	1.000	0.000	1.000	8.000	1.000	9.000	1.000	29.504
46	4	2.000	1.000	1.000	1.000	3.000	1.000	4.000	1.000	30.581
47	4	2.000	1.000	1.000	1.000	4.000	1.000	5.000	1.000	32.157
48	4	2.000	1.000	1.000	1.000	5.000	1.000	6.000	1.000	32.987
49	4	2.000	1.000	1.000	1.000	6.000	1.000	7.000	1.000	33.142
50	4	2.000	1.000	1.000	1.000	7.000	1.000	8.000	1.000	31.788
51	4	2.000	1.000	2.000	1.000	8.000	1.000	9.000	1.000	30.000

Res3DInv data format – extra header for IP

When IP data is present a few extra header lines are added, these are added after the “number of data points” line:

4	2	End of grid definition					
5	712	Number of data points					
6	IP present	IP header					
7	Chargeability	Type of IP data					
8	mV/V	Unit for IP data					
9	0.1,1.0	Delay and integration time for IP data					
10	0.000	0.000	1.000	0.000	10.0544	0.3702	Data lines
11	0.000	0.000	2.000	0.000	10.1311	0.8952	
12	0.000	0.000	3.000	0.000	10.1860	1.3004	
13	0.000	0.000	4.000	0.000	10.1808	1.3179	
14	0.000	0.000	5.000	0.000	10.1235	0.9504	
15	0.000	0.000	6.000	0.000	10.0573	0.4828	
16	0.000	0.000	7.000	0.000	10.0095	0.1319	
17	0.000	0.000	0.000	1.000	10.0544	0.3700	
18	0.000	0.000	1.000	1.000	10.1214	0.8158	
19	0.000	0.000	0.000	2.000	10.1312	0.8948	
20	0.000	0.000	2.000	2.000	10.4994	3.1920	
21	0.000	0.000	0.000	3.000	10.1860	1.2999	
22	0.000	0.000	3.000	3.000	10.5749	4.4965	
23	0.000	0.000	0.000	4.000	10.1808	1.3179	
24	0.000	0.000	4.000	4.000	10.0542	1.8797	
25	0.000	0.000	0.000	5.000	10.1235	0.9505	
26	0.000	0.000	5.000	5.000	9.5838	-2.3194	
27	0.000	0.000	0.000	6.000	10.0572	0.4825	
28	0.000	0.000	6.000	6.000	9.6499	-2.2744	

Topography options

Several options:

Z-coordinates on point/arbitrary electrodes (XXX slides back)

Topography in a structured list

```

7.000 10.000 9.000 10.000 124.2985
7.000 10.000 10.000 10.000 120.3522
8.000 10.000 9.000 10.000 115.0855
8.000 10.000 10.000 10.000 113.3131
9.000 10.000 10.000 10.000 102.7262
Topography
2
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0.00 0.00 0.00 -0.50 -1.00 -1.50 -1.00 -0.50 0.00 0.00 0.00
0
0
0
0

```

Last data lines

Topography header
Surface distances used, 1 for true horizontal/global distances

Elevation of all grid nodes, in x→ and y↓ directions

End of file

Topography at specified points

```

7.000 10.000 9.000 10.000 124.2985
7.000 10.000 10.000 10.000 120.3522
8.000 10.000 9.000 10.000 115.0855
8.000 10.000 10.000 10.000 113.3131
9.000 10.000 10.000 10.000 102.7262
Topography
2
Topography in unstructured list
Number of topography data points
121
Topography data points (index,x,y,z)
1 0.0 0.0 0.00
2 1.0 0.0 0.00
3 2.0 0.0 0.00
4 3.0 0.0 -0.50
5 4.0 0.0 -1.00
6 5.0 0.0 -1.50
7 6.0 0.0 -1.00
8 7.0 0.0 -0.50
9 8.0 0.0 0.00
10 9.0 0.0 0.00

```

Last data lines

Topography header
Surface distances used, 1 for true horizontal/global distances

Header for topography at specified points

Header for number of topography points

Number of topography points

Header
Point number, x, y and z coordinate

Inversion settings & other options

The inversion and settings and other options are very similar to Res2DInv

- **Smoothness constrained (L2) and and robust/blocky (L1 norm) inversion methods**
- **Limit on model resistivities, vertical and horizontal flatness filters etc.**
- **Underwater surveys and buried electrodes**
- **Fixed regions and known boundaries**

Special options in Res3DInv

- **Combination of Res2DInv data files into Res3DInv data files**
- **Time lapse inversion for tracking the changes in datasets and models between measurements**
- **Used for monitoring lands slides, injections, migration of tracers/pollutions and remediation**

Combine Res2DInv data files into Res3DInv data files

Lines in an orthogonal grid

```

1 Collate 3 Lines Title line
2 Number of files to collate Header for number of files to combine
3 3 Number of files to combine
4 File 1 parameters Header for file 1
5 Name of data file in RES2DINV format Header for file name
6 d:\test\FILE2D_1.DAT Full file path and file name for file 1
7 X and Y location of first electrode along this line Header for line location
8 0.0,0.0 X and Y location of first electrode in line
9 Line direction (0=X,1=Y) Header for line direction
10 0 Line is in X direction (1 for Y direction)
11 Line sign (0=positive,1=negative) Header for line sign
12 0 Electrode numbers increase in positive direction in 3D grid
13 File 2 parameters Same information for file 2
14 Name of data file in RES2DINV format
15 d:\test\FILE2D_2.DAT
16 X and Y location of first electrode along this line
17 0.0,-0.5
18 Line direction (0=X,1=Y)
19 0
20 Line sign (0=positive,1=negative)
21 0
22 File 3 parameters
23 Name of data file in RES2DINV format
24 d:\test\FILE2D_3.DAT
25 X and Y location of first electrode along this line
26 0.0,-1.0
27 Line direction (0=X,1=Y)
28 0
29 Line sign (0=positive,1=negative)
30 0
31 Name of Output file in RES3DINV format Header for output file name
32 d:\test\FILE_3D.dat Full file path and file name for output file
33 End of file

```

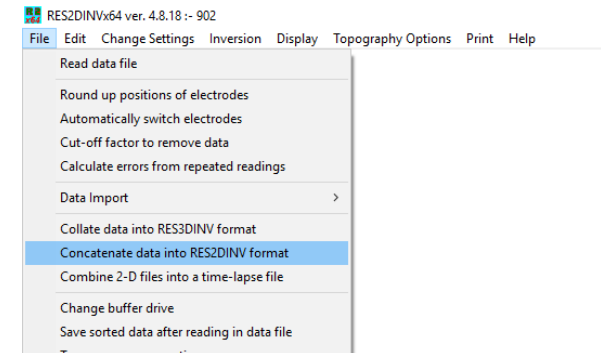
Lines in arbitrary directions

```

1 3-D arbitrary electrodes data format Title line
2 Number of files to collate Header for number of files to combine
3 3 Number of files to combine
4 Arbitrary point electrodes format Header for arbitrary electrode locations
5 X model grid spacing Header for model X discretization
6 1.0 Model discretization in X-direction
7 Y model grid spacing Header for model Y discretization
8 1.0 Model discretization in Y-direction
9 File 1 parameters Header for file 1
10 Name of data file in RES2DINV format Header for file name
11 c:\Test\block32x19b-x-00.DAT Full file path and file name for file 1
12 File 2 parameters Same information for file 2
13 Name of data file in RES2DINV format
14 c:\Test\block32x19b-x-02.DAT
15 File 3 parameters
16 Name of data file in RES2DINV format
17 c:\Test\block32x19b-x-04.DAT
18 Name of Output file in RES3DINV format Header for output file name
19 c:\Test\block32x19b-3D.dat Full file path and file name for output file
20 End of file

```

Files are combined using Res2DInv:



Data processing/removal of bad data points in Res3DInv

Due to the huge amount of data points and 3D complexity of 3D ERT data it is hard to do visual/manual processing of the data to improve inversion results, there are 2 options:

- **The statistical approach based on an initial inversion as demonstrated in Res2DInc**
- **For datasets joined of several 2D lines the manual processing can be done to the 2D lines using Res2DInv prior to combining the lines into a 3D data file**

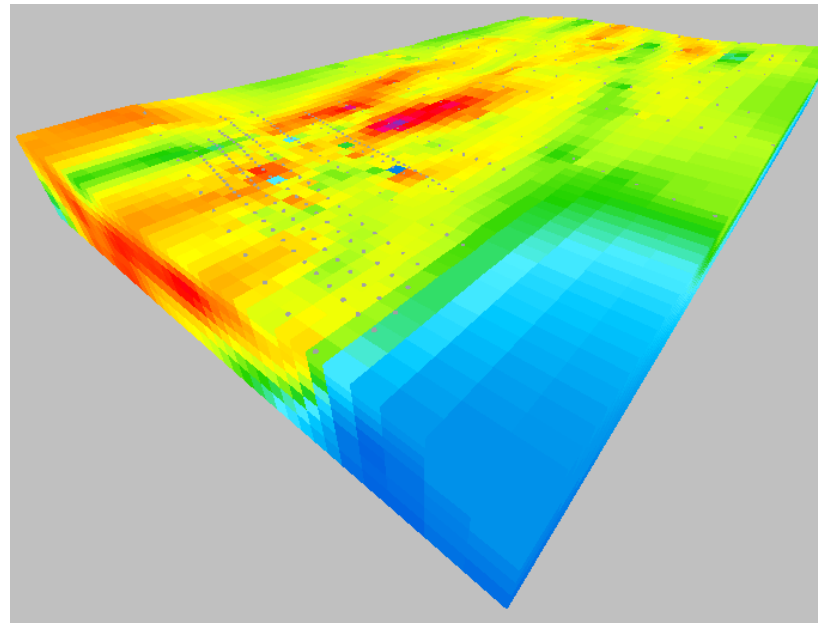
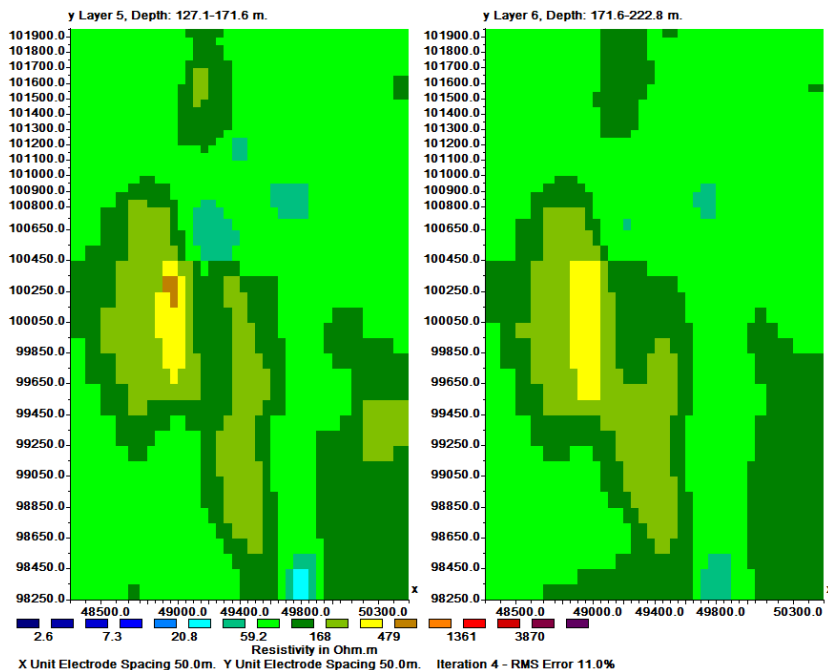
Visualization

Res3DInv has several visualization options, to enter “display mode” select ‘Display->display results’

Classic build in visualization:

3D Viewer:

Exports:

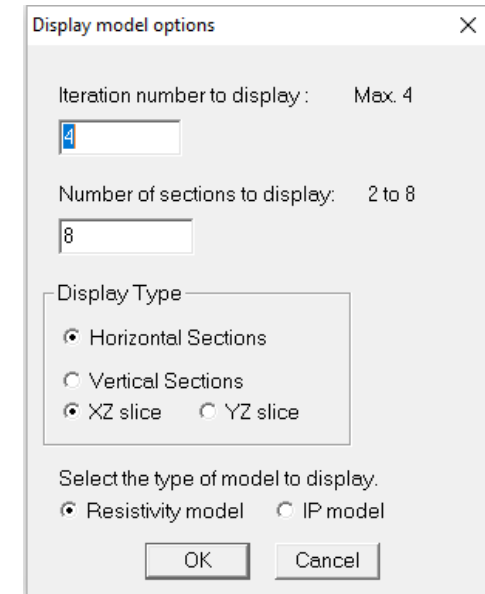
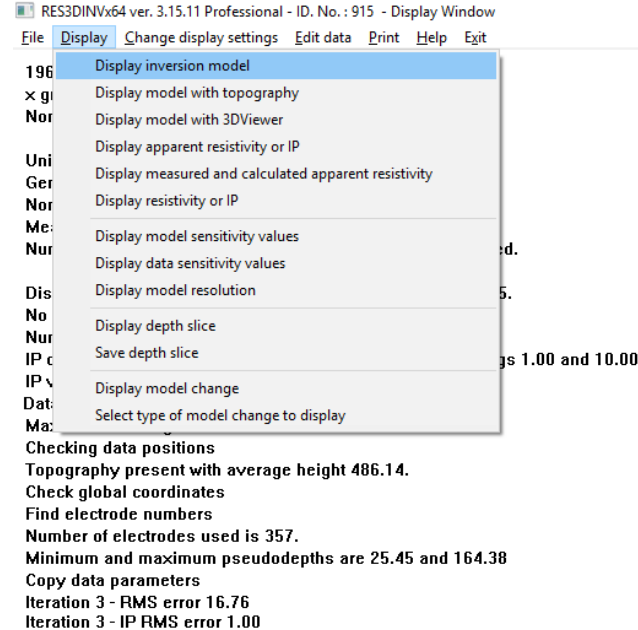
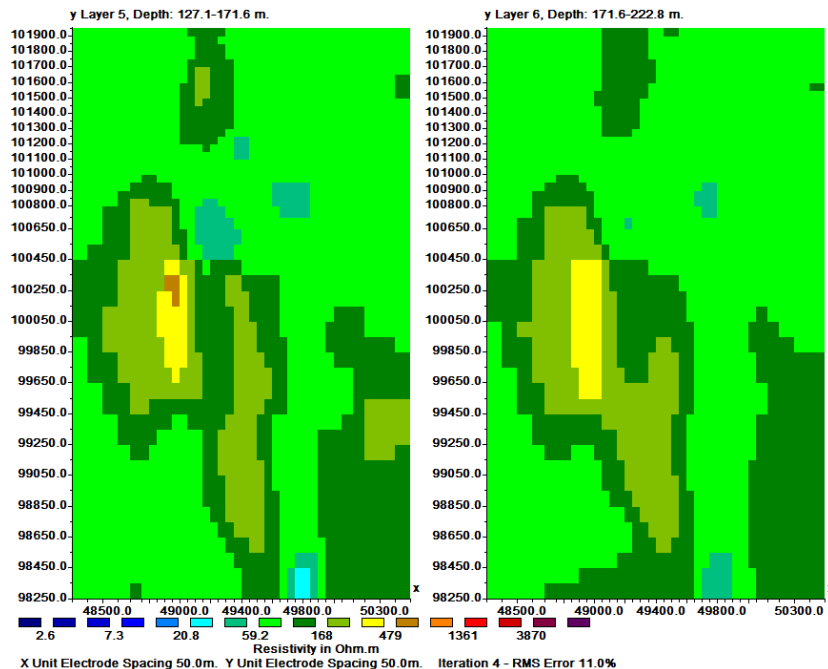


```
1 /Name of survey line is 1966_IP_data_all_final_nodtm.BDB
2 /Number of blocks is 14112
3 /Results for iteration 4
4 /The x, y and z coordinates the centres of the model blocks, and
5 /the resistivity, conductivity and IP value of each block is given below.
6 /The I.P. is given in terms of Percent Frequency Effect with units in %
7 /
```

	X	Y	Elevation	Resistivity	Conductivity
8	48350.0000	98300.0000	498.0921	78.0237	0.012817
9	48450.0000	98300.0000	496.2501	77.4654	0.012909
10	48550.0000	98300.0000	490.6038	78.3246	0.012767
11	48637.5000	98300.0000	482.8150	90.6875	0.011027
12	48712.5000	98300.0000	478.1996	71.4942	0.013987
13	48775.0000	98300.0000	474.8938	69.6839	0.014351
14	48825.0000	98300.0000	471.4896	54.0520	0.018501
15	48875.0000	98300.0000	469.1854	46.1332	0.021676
16	48925.0000	98300.0000	466.9939	36.8043	0.027171
17	48975.0000	98300.0000	465.3968	26.2511	0.038094
18	49025.0000	98300.0000	465.9678	22.3539	0.044735
19	49075.0000	98300.0000	466.1528	18.2205	0.054883
20	49125.0000	98300.0000	466.2152	16.1321	0.061988
21	49175.0000	98300.0000	469.6369	19.2623	0.051915
22	49225.0000	98300.0000	472.0463	49.2114	0.020320
23	49275.0000	98300.0000	476.6610	64.9709	0.015392
24	49325.0000	98300.0000	480.9317	212.7277	0.0047008
25	49375.0000	98300.0000	482.7738	413.8167	0.0024165
26	49425.0000	98300.0000	487.3830	84.9816	0.011767
27	49475.0000	98300.0000	490.0945	17.5093	0.057113
28	49525.0000	98300.0000	493.1746	22.2833	0.044877
29	49575.0000	98300.0000	494.3861	62.1920	0.016079
30	49625.0000	98300.0000	492.8252	122.4661	0.0081655
31	49675.0000	98300.0000	492.9211	173.3137	0.0057699
32	49725.0000	98300.0000	493.2687	160.3539	0.0062362
33	49775.0000	98300.0000	495.1201	136.4403	0.0073292
34	49825.0000	98300.0000	497.4661	237.3000	0.0042141
35	49875.0000	98300.0000	501.5447	313.0403	0.0031945

Classic build-in visualization

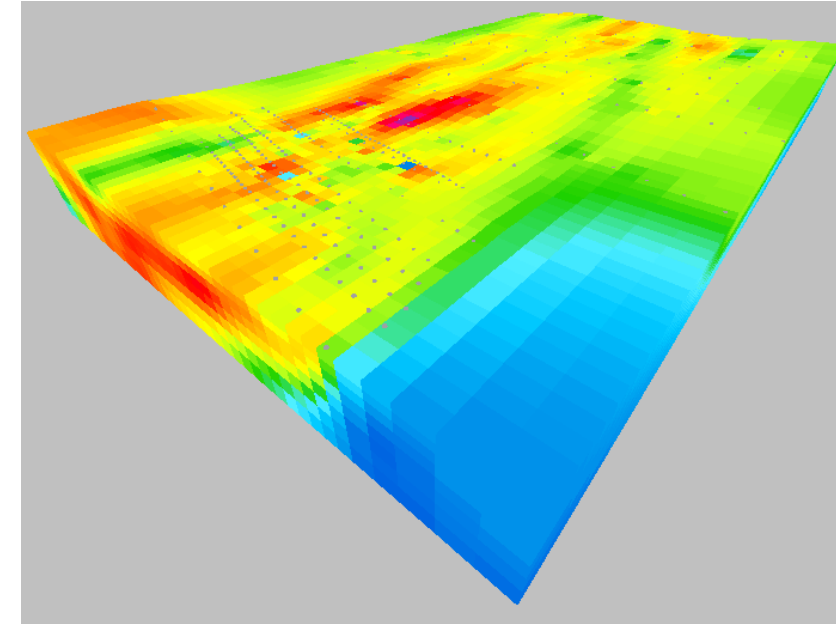
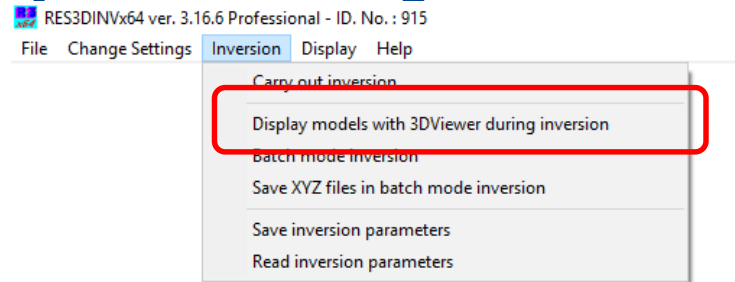
In this mode it is possible to show vertical and horizontal slices of the inverted model on a color scale, the settings and options are very similar to those of Res2DInv.



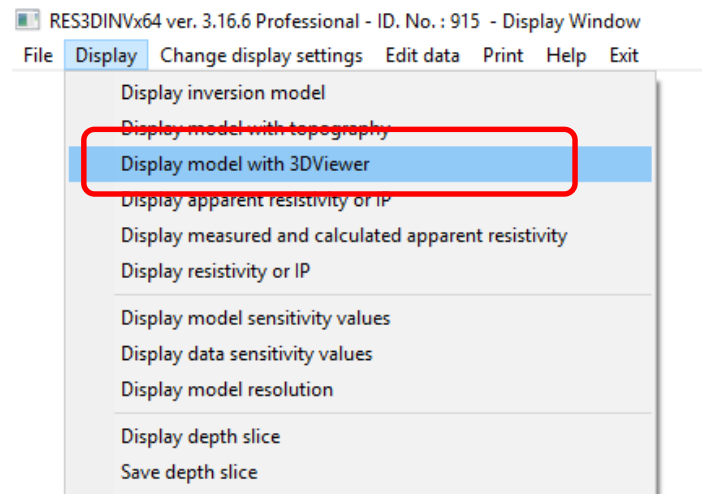
3D Viewer

Can be used to view results in 3D both during and after inversion.

To display results during inversion:



To display results after inversion in display mode:



3D Viewer – Live demo

- **Display models during inversion**

Display mode:

- **Rotation, zoom and move center**
- **Axes and center**
- **Layer selection**
- **Color scale**
- **Wire frame**
- **Cut planes and subnodes**

Bonus – Res2DInv and Res3DInv results in Aarhus Workbench

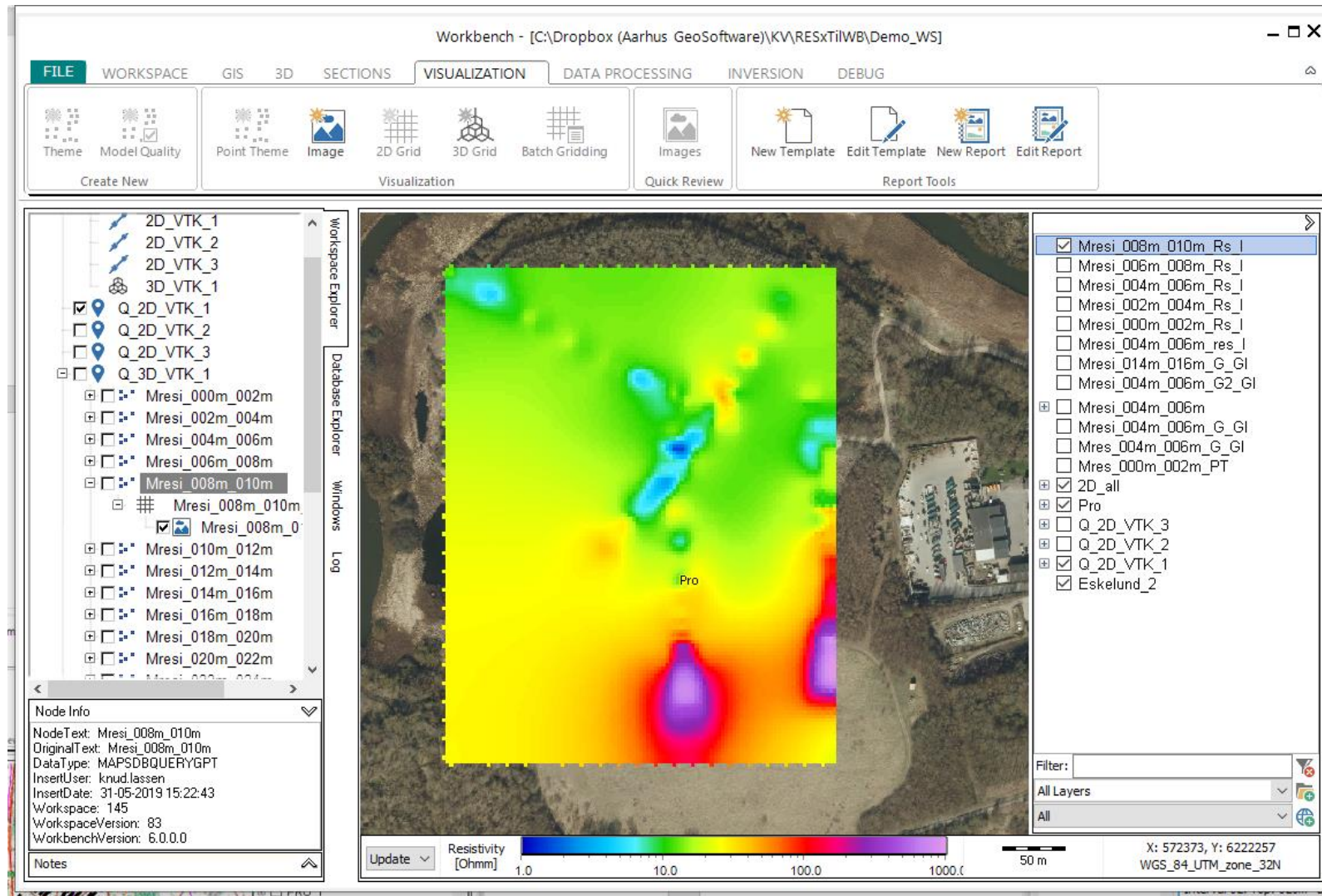
It is possible to load inversion results from Res2DInv and Res3DInv into Aarhus workbench for improved visualization and interpretation options, in the following a few examples are shown. For instruction on how to use these options please refer to the manual for using Res2DInv inversion results in Aarhus Workbench, which can be downloaded here: [XXXXXXXXX](#)

Note that these options require a Aarhus Workbench Essential License.

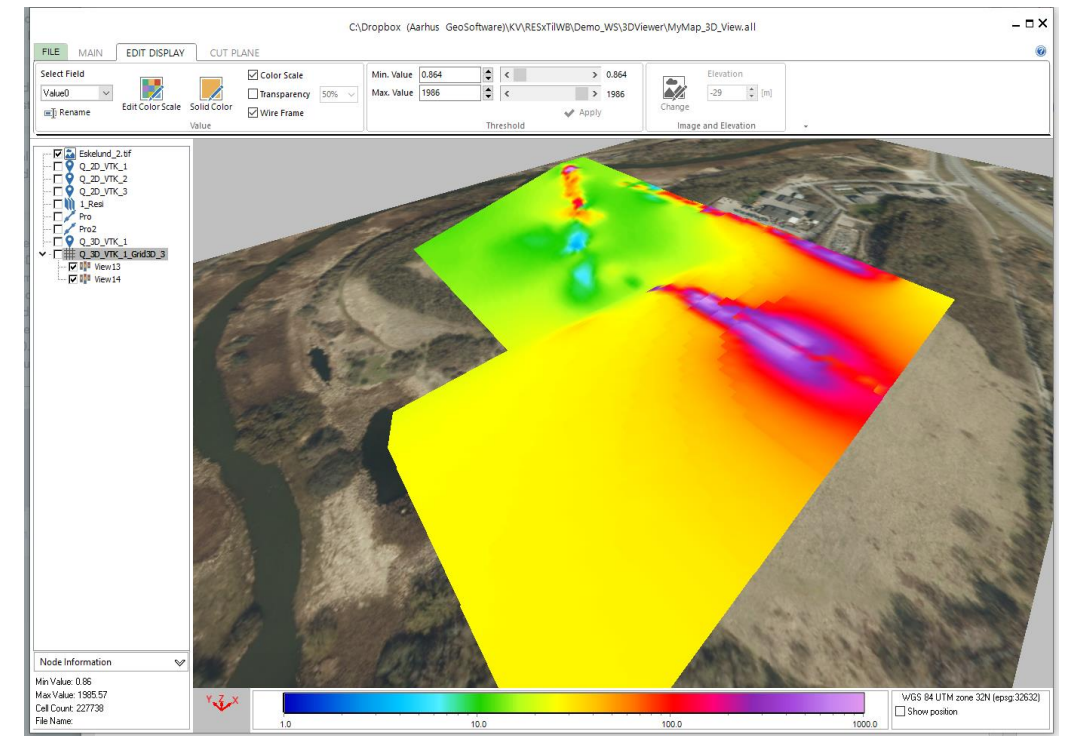
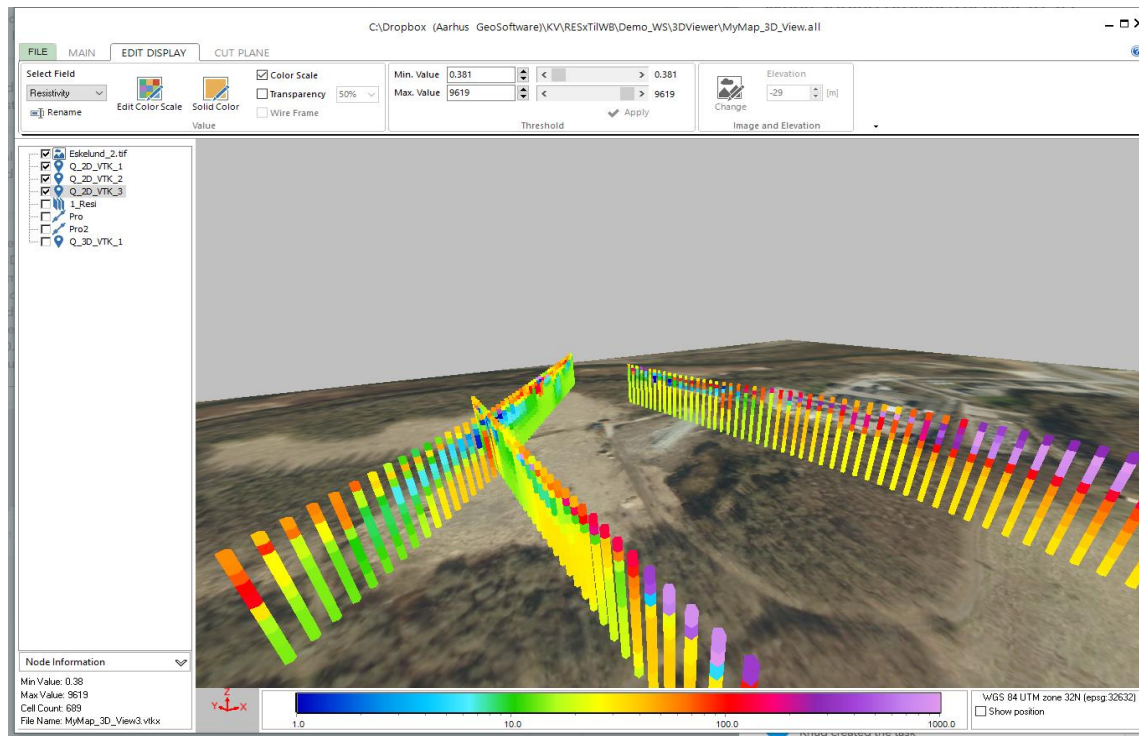
Show location of data, inversions, boreholes etc. on a GIS map



Create horizontal maps, showing e.g. mean resistivity



Display 2D and 3D inversion results in the 3D viewer



Create automatized PDF reports for fast reporting on fieldwork

Report Editor - [2018-07-02_knud.lassen] - New report, not saved

Save Load Print Page All Pages Preview Previous 1 / 1 Next New Copy Delete Increase Decrease Reset

Text
Project Title

Text
Resistivity Profiles (ohmm)

Text
Inversion type

Profile Name SW-NE-01 Axis Min/Max Mode As defined on profil Vertical Exaggeration 1: 3 X-Axis Scale 1: 20000 X Min 0.00 Y Min 0.00 X Max 0.00 Y Max 0.00

Text
The profiles display model bars from the smoi

Profile Name SW-NE-02 Axis Min/Max Mode As defined on profil Vertical Exaggeration 1: 3 X-Axis Scale 1: 20000 X Min 0.00 Y Min 0.00 X Max 0.00 Y Max 0.00

Profile Name SW-NE-03 Axis Min/Max Mode As defined on profil Vertical Exaggeration 1: 3 X-Axis Scale 1: 20000 X Min 0.00 Y Min 0.00 X Max 0.00 Y Max 0.00

Workbench Map Data Map Center (X,Y) 567670 6230656 Rotation 0 Map Scale 1: 50 000 Map Layers Show Axes Show Grid

Text
Models have been blanked by 90% below the

Text
Line 1 (South-North)

Line 1 (South-North)

Line 2 (South-North)

Line 3 (South-North)

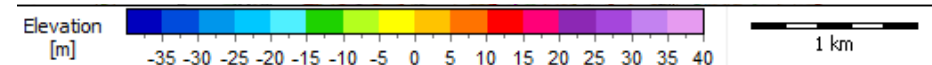
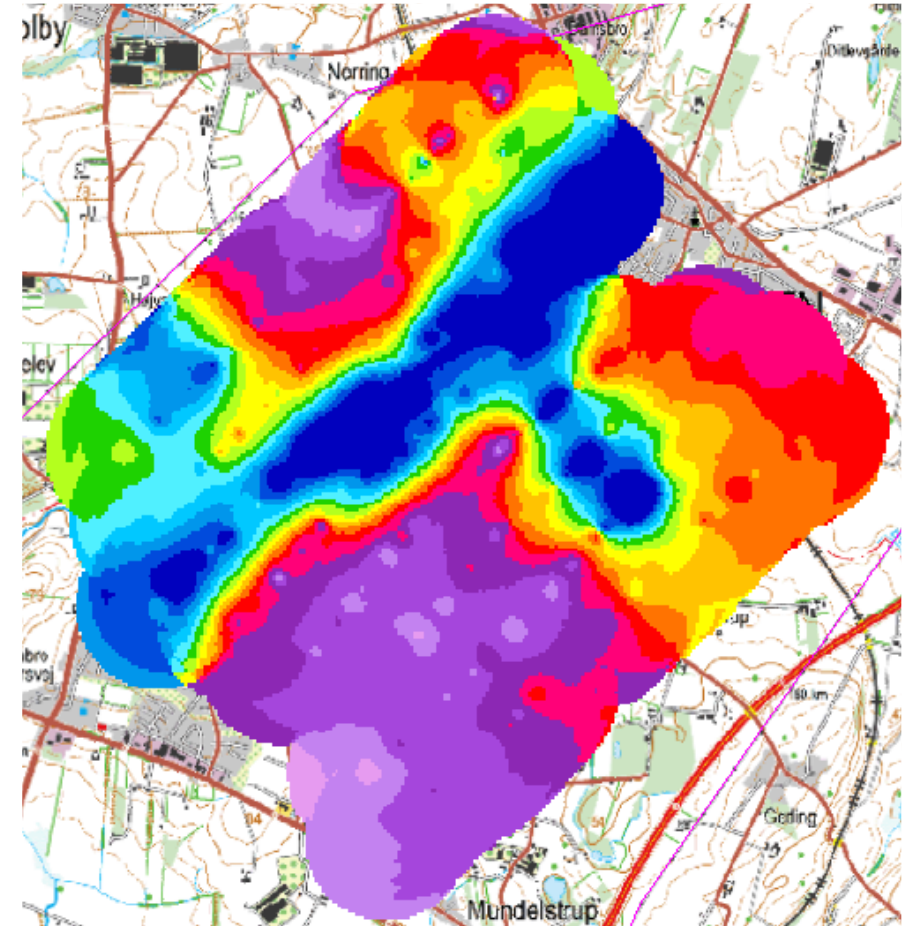
AGS Aarhus GeoSoftware

Project Title

Resistivity Profiles (ohmm)

Inversion type

The profile display model bars from the smoi inversion results. Profiles have been blanked by 90% below the GDF standard.



Thank you – questions?