Tutorial for Self Potential data processing I
Data correction

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1- Basic information about self-potential

Self-potential method is based on the measurement of naturally occurring electric potential difference in the Earth (in mV). To perform the self-potential (SP) measurements, we use a pair of nonpolarizing electrodes (Cu/CuSO4 electrodes in our case). The microporous extremity of these electrodes (made of a low-permeability wood) is put in contact with the ground. The difference of electrical potential between the reference electrode (arbitrarily placed at the beginning of the profile) and the moving electrode is measured with a calibrated high impedance voltmeter. A long wire (several hundred meters) is used to connect the two electrodes to the voltmeter. The spacing between two successive measurement-stations depends on the size of the anomalies we expect. It is commonly 20 m to have a good resolution (adapted to the dimensions of the main structural limits) and reasonable time of measurement. At each station, a small hole (~10 cm deep) is dug to improve the electrical contact between the electrode and the ground. The value of the electrical resistance is also measured prior each SP measurement to check the electrical contact between the electrodes. Each measurement is located with a GPS. A new reference station is established every time the end of the cable is reached or before (depending on the field conditions). All the measurements performed along a continuous line are named a "profile".

The measurements are generally performed forming loops (closed profiles or profiles connected at both extremities to other profiles) in order to evaluate and correct the drift undergone during the acquisition of the data. This can also be made performing the first and the last measurement at the sea. By convention, the SP value attributed to the sea is 0mV and it can be considered as a reference equipotential surface. Therefore, it is taken as a reference whenever possible.

After the survey, the entire SP database is reconstructed choosing a unique reference station. This process requires two corrections of the raw SP data:

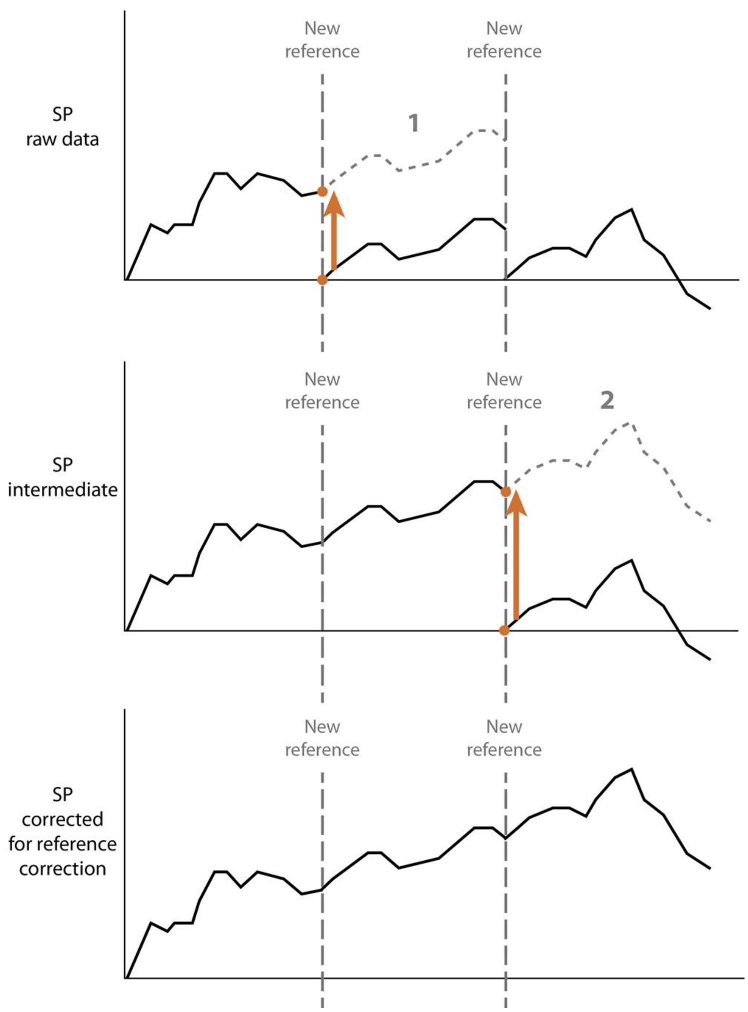
- reference correction
- closure correction (or loop correction)

We use Excel (other spreadsheet applications can be used, like Grapher) to process the data and Surfer (a contouring and 3D surface mapping program) to interpolate, build maps and graphics with the results. In a graph, SP data is represented as a function of the distance.

2- Correct a self-potential profile
2.1- Reference correction

A reference correction must be applied to a SP profile if this one has been performed changing the position of the reference electrodes.

The reference correction is made to join the different parts of a same SP profile, correcting the various changes of reference electrode. Indeed, each time the difference of electrical potential is measured from a new reference, the measurements starts again from 0 mV. Each section of the profile collected with a single reference must be shifted to the end of the previous section (see figure 2.1). Only the first section will remain unchanged will the others will be shifted section by section in the direction in which the measurements were acquired.



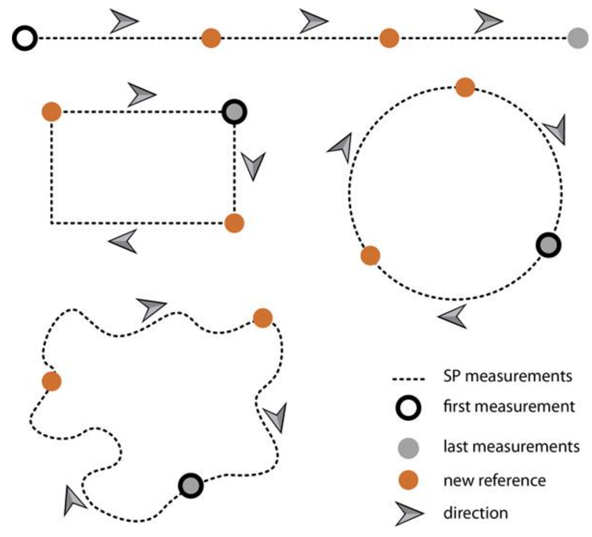
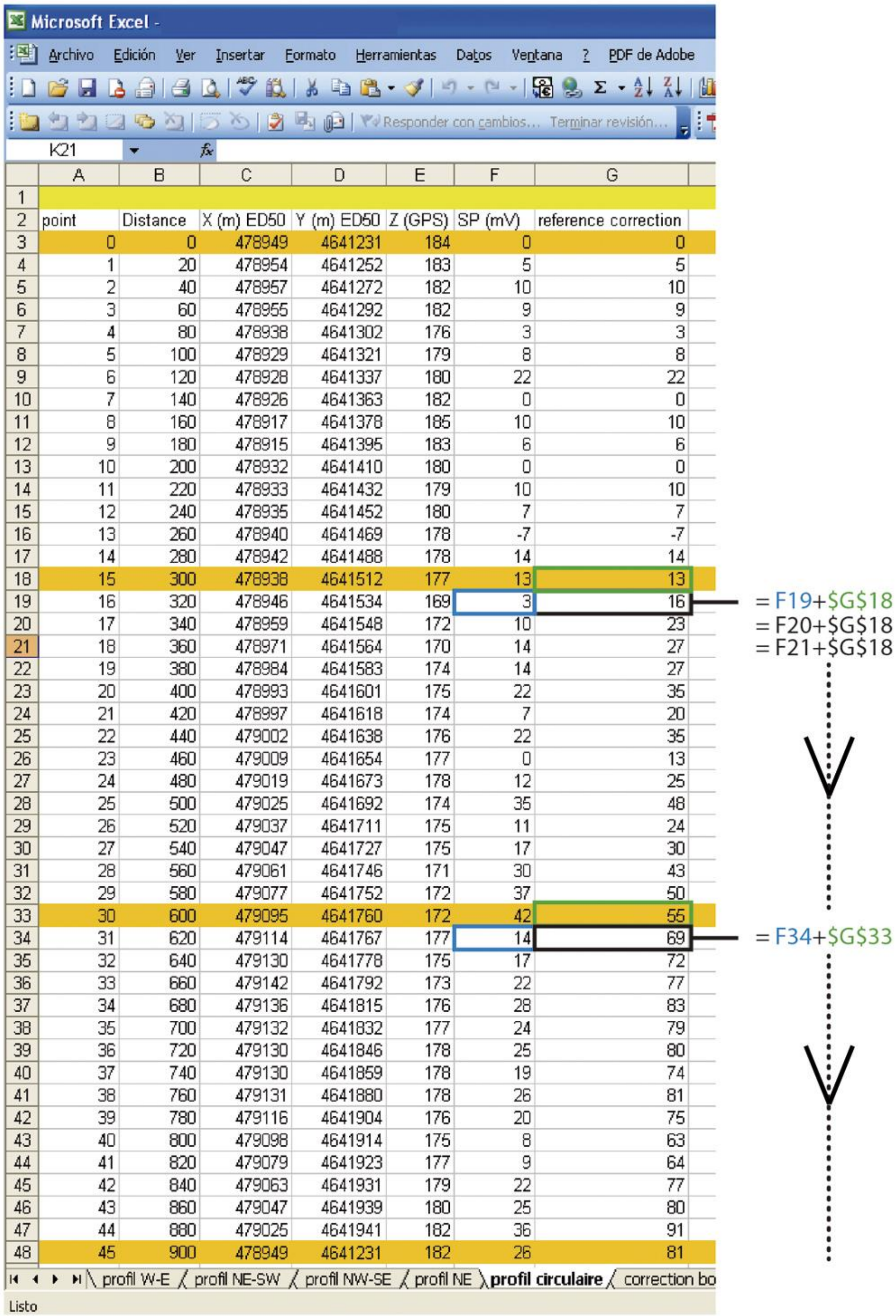


Fig. 2.1. Schematic representation of the reference correction of SP data (on the left). The orange arrows represent the shift of the data, section by section. This can be applied to any example of SP profile presented above (trace in aerial view).



	A	B	C	D	E	F	G
1							
2	point	Distance	X (m) ED50	Y (m) ED50	Z (GPS)	SP (mV)	reference correction
3	0	0	478949	4641231	184	0	0
4	1	20	478954	4641252	183	5	5
5	2	40	478957	4641272	182	10	10
6	3	60	478955	4641292	182	9	9
7	4	80	478938	4641302	176	3	3
8	5	100	478929	4641321	179	8	8
9	6	120	478928	4641337	180	22	22
10	7	140	478926	4641363	182	0	0
11	8	160	478917	4641378	185	10	10
12	9	180	478915	4641395	183	6	6
13	10	200	478932	4641410	180	0	0
14	11	220	478933	4641432	179	10	10
15	12	240	478935	4641452	180	7	7
16	13	260	478940	4641469	178	-7	-7
17	14	280	478942	4641488	178	14	14
18	15	300	478938	4641512	177	13	13
19	16	320	478946	4641534	169	3	16
20	17	340	478959	4641548	172	10	23
21	18	360	478971	4641564	170	14	27
22	19	380	478984	4641583	174	14	27
23	20	400	478993	4641601	175	22	35
24	21	420	478997	4641618	174	7	20
25	22	440	479002	4641638	176	22	35
26	23	460	479009	4641654	177	0	13
27	24	480	479019	4641673	178	12	25
28	25	500	479025	4641692	174	35	48
29	26	520	479037	4641711	175	11	24
30	27	540	479047	4641727	175	17	30
31	28	560	479061	4641746	171	30	43
32	29	580	479077	4641752	172	37	50
33	30	600	479095	4641760	172	42	55
34	31	620	479114	4641767	177	14	69
35	32	640	479130	4641778	175	17	72
36	33	660	479142	4641792	173	22	77
37	34	680	479136	4641815	176	28	83
38	35	700	479132	4641832	177	24	79
39	36	720	479130	4641846	178	25	80
40	37	740	479130	4641859	178	19	74
41	38	760	479131	4641880	178	26	81
42	39	780	479116	4641904	176	20	75
43	40	800	479098	4641914	175	8	63
44	41	820	479079	4641923	177	9	64
45	42	840	479063	4641931	179	22	77
46	43	860	479047	4641939	180	25	80
47	44	880	479025	4641941	182	36	91
48	45	900	478949	4641231	182	26	81

Fig. 2.2. Reference correction of the SP data in Excel.

The reference correction is made section by section of the profile, from one reference to the next one. In the Excel sheet, we must add the last value of the previous section to all the measurements of the section we are currently correcting. In Figure 2.2, the new references are evidenced by the orange rows. These orange rows correspond to the orange dots in Figure 2.1).

The initial section (row 3 to 18) depends directly on the first reference so that no correction is applied to it. Section 1 (from row 19 to 33 in this example) is shifted to the last value of the initial section; section 2 (row 34 to 48) is shifted to the last value of section 1. We write the formula at the first row of each section and drag it until the last row of the same section.

2.2- Closure correction

In the case of a closed profile, the first point is identical to the last one so the SP value measured should theoretically be the same. This would be true if no environmental perturbation occurred between the moments when the first and the last measurements were made. However during the survey, the measurement conditions can change (e.g. soil moisture, soil temperature, instrumental error, etc…) and a drift will be observed. Using nonpolarizing electrodes drastically reduces the instrumental drift.

We consider that the drift increases regularly from the first point to the last one: along the period of time of the acquisition, the drift accumulates. This drift is considered as parasitic and it must be corrected. This is the closure correction.

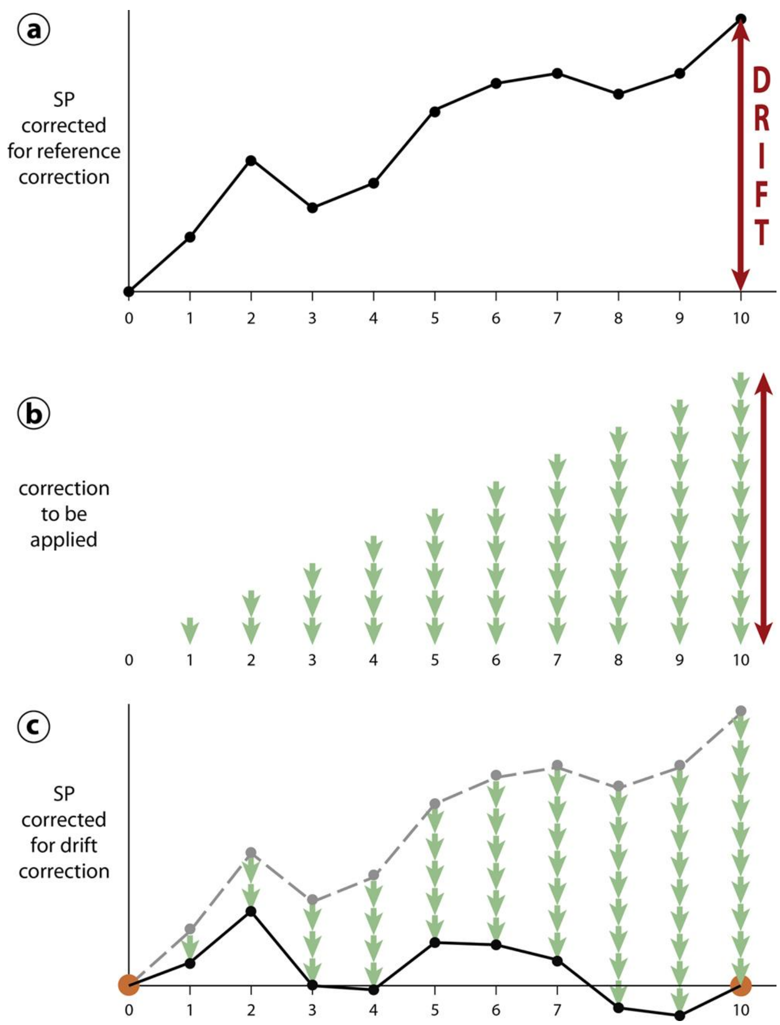


Fig. 2.3. Schematic representation of the closure correction of SP data in a closed profile composed of 10 datapoints. Point 0 and point 10 are geographically the same.

In the example presented in Figure 2.3, we imagine a dataset containing 10 datapoints and where the first point is geographically the same than the last one (closed profile).

Fig. 2.3a: the drift is the difference of SP between the first and the last point.

Figure 2.3b and c: the correction of this drift is applied on all the datapoints of the profile, increasing the correction factor from the first to the last point. The initial point is the reference of the profile so that no correction is applied to it. The first point (after the reference) will be corrected for $1/10^{th}$ of the total drift (where10 is the number of data points without counting the reference). The second point will be corrected for $2/10^{th}$ of the total drift, etc… until the last point which will be corrected for $10/10^{th}$ of the drift (i.e. the total drift) because it must reach the same value than the reference point (see the orange dots in Figure 2.3c).

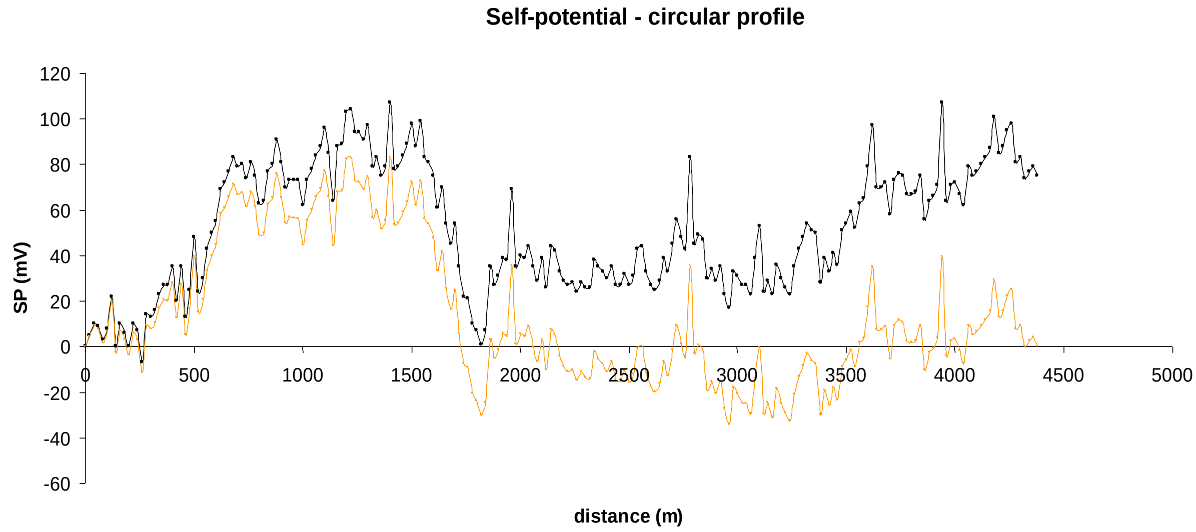


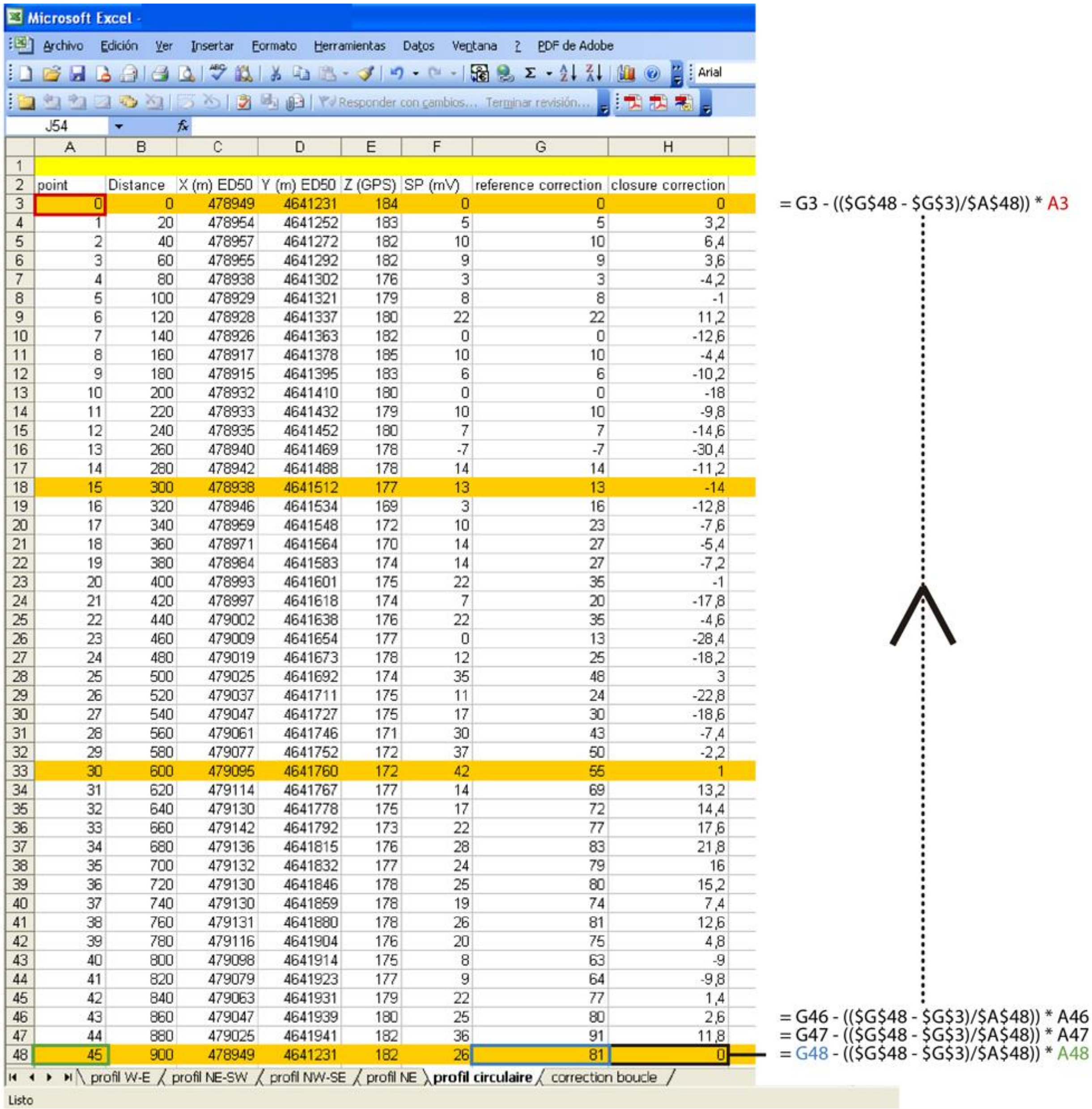
Fig. 2.4. Example of real-case closure-correction on a closed SP-profile. The black line is from the original dataset (previously corrected for the reference correction) and the orange line is the same profile corrected for the closure correction. Note that the last point is corrected to reach the same value than the reference point (geographically the same point). Also note how this correction deforms the graph without eliminating the SP anomalies (positive and negative peaks).

In the following example Excel-sheet (Fig. 2.5) we can notice that the reference point (row 3) and the last point (row 48) have the same X and Y GPS coordinates but a different SP value after reference correction (see cell G3 and G48). As said before, this difference is the drift that we must correct. The correction is made in column H and the corresponding equation is presented on the right side of the figure.

First we must create a column with the numeration of the datapoints, beginning at 0 for the reference (see column A). This column will be used to settle the “degree of correction” applied to each point: the reference will need no correction; that is why we assign it the number 0 (cell A3). The correction begins at the last point and is dragged until the reference point. This allows to see immediately if the formula has been written properly (by comparing the result with the reference point). Some elements of the equation are constants but other will vary as the correction is applied unequally to each point of the profile.

The closure-correction equation is: **SPc = SPr - (D / N) * n**

Where **SPc** is the SP value corrected from the closure correction
SPr is the SP value corrected from the reference correction
D is the drift
N is the total number of datapoint in the profile
n is the place of the datapoint in the profile



	A	B	C	D	E	F	G	H
1								
2	point	Distance	X (m) ED50	Y (m) ED50	Z (GPS)	SP (mV)	reference correction	closure correction
3	0	0	478949	4641231	184	0	0	0
4	1	20	478954	4641252	183	5	5	3,2
5	2	40	478957	4641272	182	10	10	6,4
6	3	60	478955	4641292	182	9	9	3,6
7	4	80	478938	4641302	176	3	3	-4,2
8	5	100	478929	4641321	179	8	8	-1
9	6	120	478928	4641337	180	22	22	11,2
10	7	140	478926	4641363	182	0	0	-12,6
11	8	160	478917	4641378	185	10	10	-4,4
12	9	180	478915	4641395	183	6	6	-10,2
13	10	200	478932	4641410	180	0	0	-18
14	11	220	478933	4641432	179	10	10	-9,8
15	12	240	478935	4641452	180	7	7	-14,6
16	13	260	478940	4641469	178	-7	-7	-30,4
17	14	280	478942	4641488	178	14	14	-11,2
18	15	300	478938	4641512	177	13	13	-14
19	16	320	478946	4641534	169	3	16	-12,8
20	17	340	478959	4641548	172	10	23	-7,6
21	18	360	478971	4641564	170	14	27	-5,4
22	19	380	478984	4641583	174	14	27	-7,2
23	20	400	478993	4641601	175	22	35	-1
24	21	420	478997	4641618	174	7	20	-17,8
25	22	440	479002	4641638	176	22	35	-4,6
26	23	460	479009	4641654	177	0	13	-28,4
27	24	480	479019	4641673	178	12	25	-18,2
28	25	500	479025	4641692	174	35	48	3
29	26	520	479037	4641711	175	11	24	-22,8
30	27	540	479047	4641727	175	17	30	-18,6
31	28	560	479061	4641746	171	30	43	-7,4
32	29	580	479077	4641752	172	37	50	-2,2
33	30	600	479095	4641760	172	42	55	1
34	31	620	479114	4641767	177	14	69	13,2
35	32	640	479130	4641778	175	17	72	14,4
36	33	660	479142	4641792	173	22	77	17,6
37	34	680	479136	4641815	176	28	83	21,8
38	35	700	479132	4641832	177	24	79	16
39	36	720	479130	4641846	178	25	80	15,2
40	37	740	479130	4641859	178	19	74	7,4
41	38	760	479131	4641880	178	26	81	12,6
42	39	780	479116	4641904	176	20	75	4,8
43	40	800	479098	4641914	175	8	63	-9
44	41	820	479079	4641923	177	9	64	-9,8
45	42	840	479063	4641931	179	22	77	1,4
46	43	860	479047	4641939	180	25	80	2,6
47	44	880	479025	4641941	182	36	91	11,8
48	45	900	478949	4641231	182	26	81	0

Fig. 2.5. Closure correction of the SP data in Excel.

In the example shown in Fig. 2.5, the correction equation in Excel is composed as follow:

- Calculus of the drift (**D**) **= $G$48 - $G$3** (1)

This is a constant in the equation for all the profile (that is why we use the $ sign).

- Divide the drift by the number of datapoints in the profile (**N**; also a constant).
  = **(**$G$48 - $G$3**)/$A$48** (2)

- Multiply by the place of the point in the profile (**n**; variable)
  = **(**($G$48 - $G$3)/$A$48)**) * A48** (3)

This is a variable → A48 is for the correction applied to the last point. When we will drag the formula in the Excel sheet, this will change as a function of the row (that is why we do not use the $ sign in this part of the equation).

- Subtract this value to the SP value already corrected for the reference correction (**SPr**)

= **G48 -** (($G$48 - $G$3)/$A$48)) * A48 (4)

This is also a variable that will change when we drag the formula.

Remark: *note that equation (3) correspond to green arrows in figure 2.3.c and d*

3- Correct a dataset of several profiles

3.1- Overview

As seen before, SP measurements are performed forming loops in order to estimate the drift and correct it (closed profiles or profiles closed one on the other). When a dataset is composed of several profiles (in areas covered to build a SP map), each profile must be corrected independently for the reference correction, as described in section 2.1.

Remark: *In all the following description of the correction process we consider that the reference correction has been performed on all the profiles.*

After the reference correction, each profile has got its unique reference at 0 mV. In order to join all the profiles together, we must choose a first loop which will be the reference closed profile for the next steps of the closure correction (see step 1 for a, b, c, and d in Figure 3.1). The other profiles will then be used to form several loops, joined step by step to the data already corrected.

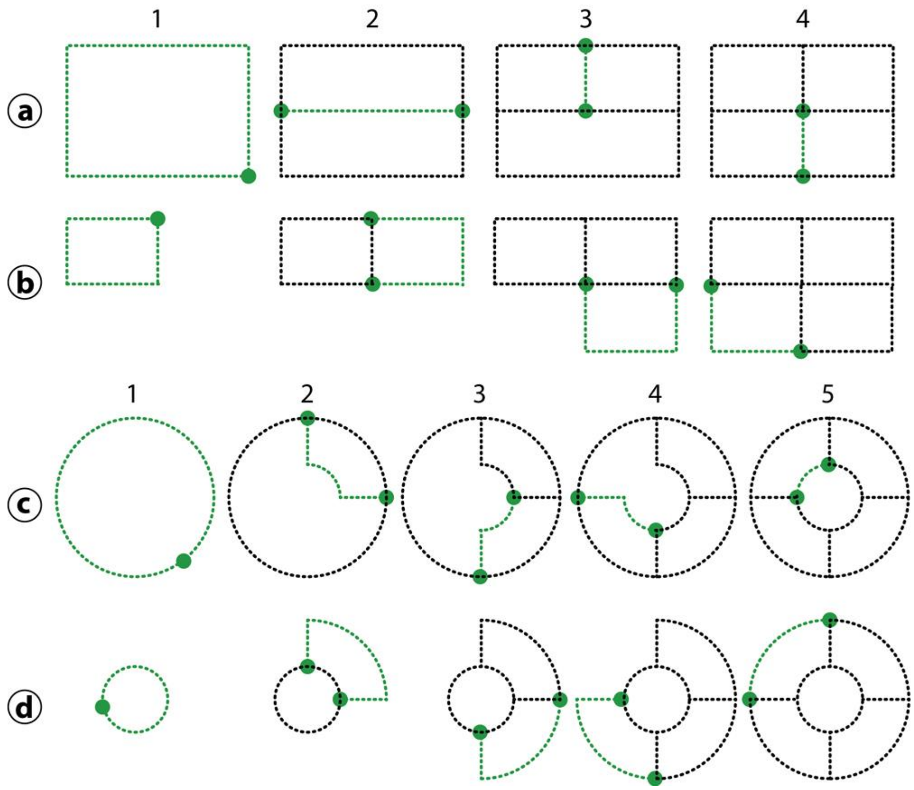


Fig. 3.1. Two examples of data networks corrected for the closure correction.
a and **b** show two alternatives of the closure correction of a simple grid.
c and **d** show two alternatives of the closure correction of a "volcano-type" network (circular profiles around the crater and the base of the cone + radial profiles on the flanks).
In the successive steps, the black doted lines are the data already corrected. The green doted lines are the loops connected step by step to the data already corrected.

In the successive steps proposed in Figure 3.1, the black doted lines are the data already corrected. Steps a4, b4, c5, and d5 correspond to the complete datasets. The green sections are the loops connected step by step to the data already corrected. A loop can be composed of part of one profile, a single profile or more than one profile. A valid loop is a section which two extremities are connected to sections already corrected for the closure correction but that does not include other points already corrected.
Remark: *a rule to keep in mind is that after being corrected for the closure correction, a datapoint is fixed → its value cannot be modified during the following steps of correction.*

The closure correction can be summarized as follow:
Step 1: correct the first reference loop ⇔ closed profile or profile connected at both extremities to the same equipotential surface (e.g. the sea). This step is described in section 2.2 of this tutorial.
Step 2: connect the next loop to the reference loop (see the following section 3.2):
- Choose the next loop to be corrected in the remaining uncorrected data
- Shift and apply a closure correction to the new loop

Step 3, 4, 5…: connect the next loop to the data already corrected (reference loop and loop of the previous steps):
- Choose the next loop to be corrected in the remaining uncorrected data
- Shift and apply a closure correction to the new loop

3.2- Connect a new loop to the reference

Remember that after the reference correction, all the profiles have a reference (first point of the profile) at 0 mV. After step 1 (see section 3.1) we choose a second loop to correct.

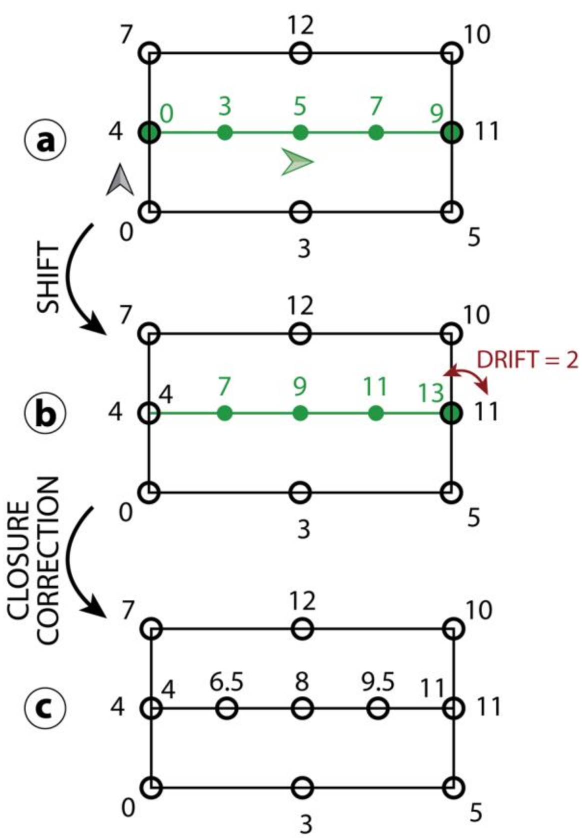


Fig. 3.2. Schematic decomposition of step 2 of the closure correction in a dataset of several profiles (see Figure 3.1.a). The black circles are datapoints already corrected for the closure correction (at step 1 in Figure 3.1). The green dots are the data to be corrected now. The numbers are the SP values for each datapoint (in mV). The arrows represent the direction of measurement in the field.

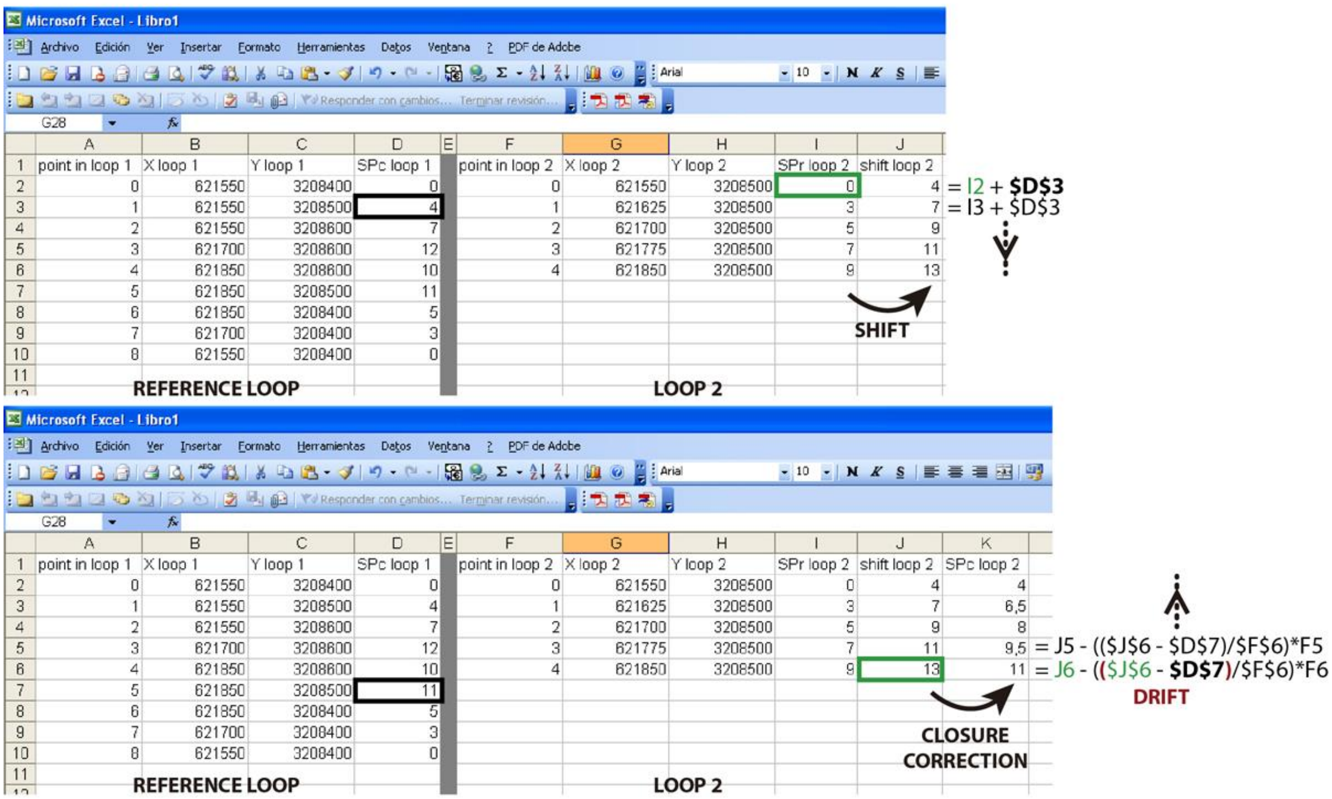
The SP values at the two connections between the loops are not equals (Fig. 3.2.a). We first must connect one extremity of the new loop to the data already corrected. For that purpose, the data from the new loop (green) are shifted so that one extremity of the new loop is equal to the same geographical point in the corrected (black) data. In our example, the green loop is shifted of 4 mV to have the first point coinciding with the black reference loop. This extremity is chosen as a function of the direction of the measurement in the field.

In the Excel sheet we add the SP value from the reference loop, at the connection, to all the points of the new loop (Fig. 3.3).

On Figure 3.2.b we observe that, after the shift, the other extremity of the new loop is not equal to the same geographical point in the reference loop. The difference observed is the drift that must be corrected following the closure correction equation (see section 2.2).

In the Excel sheet (Fig. 3.3) we apply the equation using the data from the two connected loops and drag the formula along all the data of the loop to be corrected.

At the end of step 2, the two extremities of the newly corrected loop must be at the same SP value that the reference loop (Fig. 3.2.c). The data from this loop are now fixed and can be used in the next steps of the correction (as schematized in Fig. 3.1).



	A	B	C	D	E	F	G	H	I	J
1	point in loop 1	X loop 1	Y loop 1	SPc loop 1		point in loop 2	X loop 2	Y loop 2	SPr loop 2	shift loop 2
2	0	621550	3208400	0		0	621550	3208500	0	4
3	1	621550	3208500	4		1	621625	3208500	3	7
4	2	621550	3208600	7		2	621700	3208500	5	9
5	3	621700	3208600	12		3	621775	3208500	7	11
6	4	621850	3208600	10		4	621850	3208500	9	13
7	5	621850	3208500	11						
8	6	621850	3208400	5						
9	7	621700	3208400	3						
10	8	621550	3208400	0						

	A	B	C	D	E	F	G	H	I	J	K
1	point in loop 1	X loop 1	Y loop 1	SPc loop 1		point in loop 2	X loop 2	Y loop 2	SPr loop 2	shift loop 2	SPc loop 2
2	0	621550	3208400	0		0	621550	3208500	0	4	4
3	1	621550	3208500	4		1	621625	3208500	3	7	6,5
4	2	621550	3208600	7		2	621700	3208500	5	9	8
5	3	621700	3208600	12		3	621775	3208500	7	11	9,5
6	4	621850	3208600	10		4	621850	3208500	9	13	11
7	5	621850	3208500	11							
8	6	621850	3208400	5							
9	7	621700	3208400	3							
10	8	621550	3208400	0							

Fig. 3.3. Closure correction of the SP data for the example schematized in Figure 3.2. Loop 1 is the reference loop (black colour in Fig. 3.2); Loop 2 is the new loop (to be corrected; green colour in Fig. 3.2). The upper part of the figure refer to the shift of the SP data and the lower part to the closure correction strictly speaking.

Tutorial for Self Potential data processing II
Data presentation in Surfer

SP data can be presented in graphs as a function of the distance or as a function of the altitude. The study of this type of graph can be interpreted for localizing discontinuities in the soil (e.g. circulation of fluids along faults), hydrothermal convection, etc… Usually this can be done joining the results of other geophysical or geochemical methods. With an appropriate dataset, we can also present SP data in maps.

This part of the tutorial presents the various options you can use to present self-potential (SP) data with Surfer. It can be applied to other types of data but we will take the example of SP data all along the tutorial. It does not describe the Surfer functionalities with full details as this information is clearly described in the Surfer help.

1- Starting with Surfer

Surfer is a gridding, contouring and surface mapping program.

File | New allows to create maps in a **Plot Document** or to manage data in a **Worksheet** (Fig. 1.1). Excel files can be used in Surfer and offer more possibilities to manage the data than Surfer worksheets. Surfer also allows opening .dat, .txt and other data file formats.

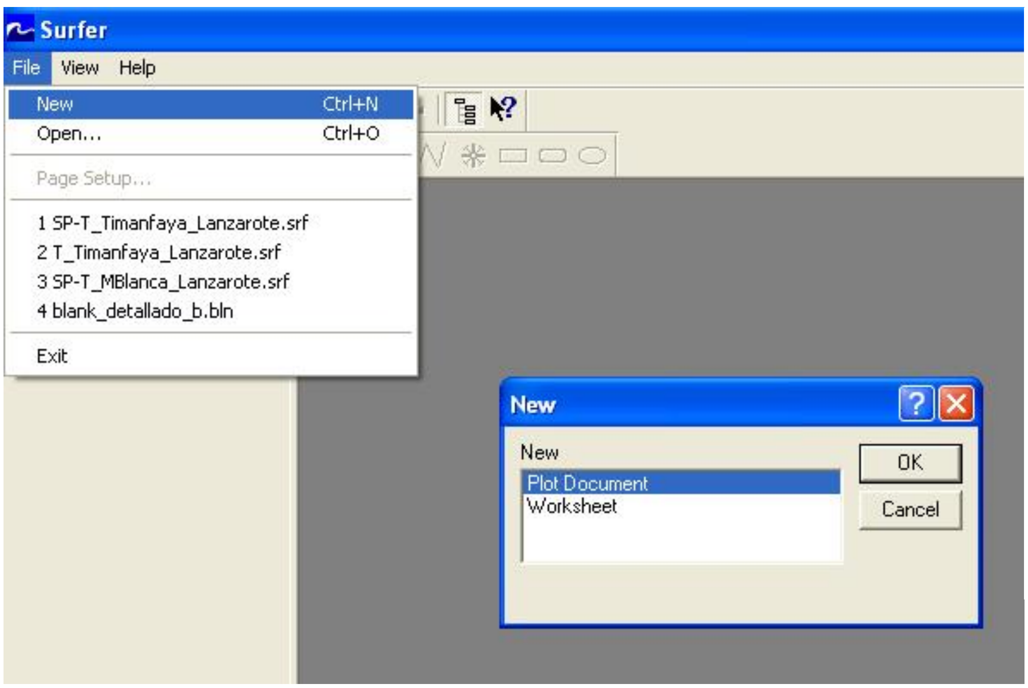


Fig. 1.1. Image capture of the **File | New** command.

2- Main menus in a Plot Document

In addition to the basic and intuitive menus (File, Edit, etc…), two key menus for creating maps in a plot document of Surfer are the **Grid** and **Map** menus (Fig. 2.1). The **Grid** menu leads to several commands used to manage data files (create a grid, extract part of a grid, modify the data into a grid, etc…). The **Map** menu allows choosing among several map representations (contour, images with a colour-scale, shaded relief, surface, etc…). Most of the commands available in the Map menu create maps based on a grid.

The third useful menu is the **Help** menu where full step by step descriptions and definitions of the Surfer function are available. You can also follow tutorials for the main functionalities of Surfer.

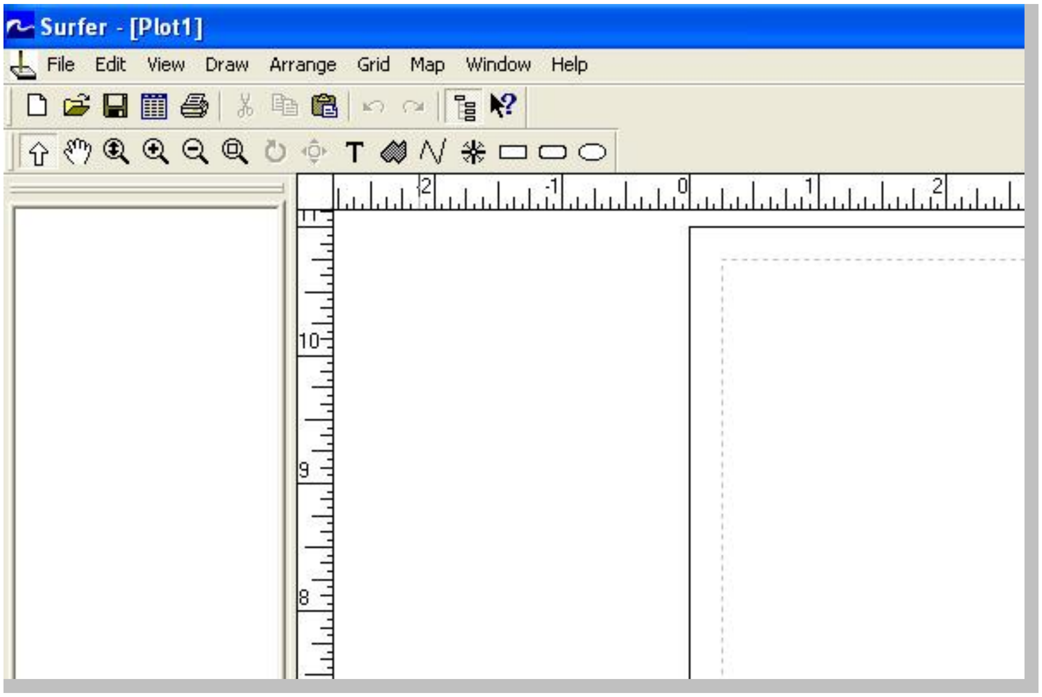


Fig. 2.1. Image capture of the **Plot** page, showing the available menus.

3- Working on self-potential data

For creating SP maps we must use the file containing the SP data corrected for the reference and the closure corrections. We also need the X and Y GPS coordinates.

3.1- Create a grid

Data-files contain data acquired in the field, often with an irregular geographical repartition. This data must be converted into an evenly spaced grid before using many of Surfer's features. A grid file contains a list of Z values (corresponding to the SP data, in our case) organized in rows and columns. The position of a data value into the grid corresponds to the X and Y geographical coordinates of the datapoints.

(1) Prepare the Excel file

In Excel, create a worksheet where all the corrected SP data are copied in one column. The corresponding X and Y coordinates must fill two other columns. The worksheet can contain title-rows and other columns.

(2) Create the grid in Surfer

- Grid files are produced using the **Grid | Data** command.
- This opens a window where you must select and open the Excel file containing your SP data.

- If the Excel file contains more than one worksheet, you will have to pick the one created at step (1).
- A new window opens to adjust the gridding parameters (Fig. 3.1)

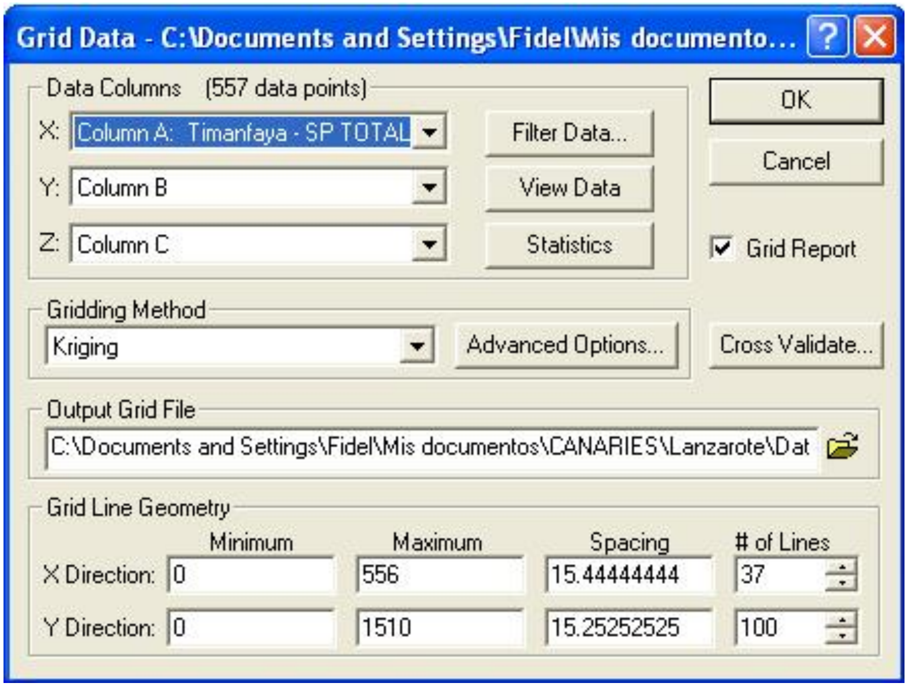


Fig. 3.1. Image capture of the **Grid | Data** command.

- In that window you must select the columns of the Excel worksheet corresponding to the geographical coordinates (X and Y) and to the SP data (Y).
- Create an output grid file clicking on the  button to change the filename and choose an emplacement to save the file.
- Click on OK.
- Close the Surfer confirmation window and close or save the Surfer gridding report (we usually close it without saving) appearing on the screen after the end of the process.
- Your grid file is saved and ready to be used.

Remark: *creating a grid file you can usually accept all of the default gridding parameters (Gridding Method and Grid Line Geometry) and generate a grid file that represents your data well.*

The repartition of SP measurements in the field is often irregular and the grid can be affected. A solution for a better result is to perform two successive griddings of the data:
- Use the **Grid | Data** command to create a grid with a spacing about five times the spacing of the measurements along the profiles (i.e. enter manually a 100 m spacing value in X and Y for a field measurement spacing of 20 m).
- The resulting grid must now be added to the original dataset. Use the **Grid | Convert** command to convert your .grd file in an **ASCII XYZ** file. The resulting file is a .dat that you can open in Excel or in a Surfer worksheet. Copy the data from the converted grid in the same worksheet that the original data.
- Use this new file and the **Grid | Data** command to create a new grid with a spacing equal to the spacing of the measurements in the field (20 m if we follow the same example).

The resulting grid is the one you can use to create your SP maps.

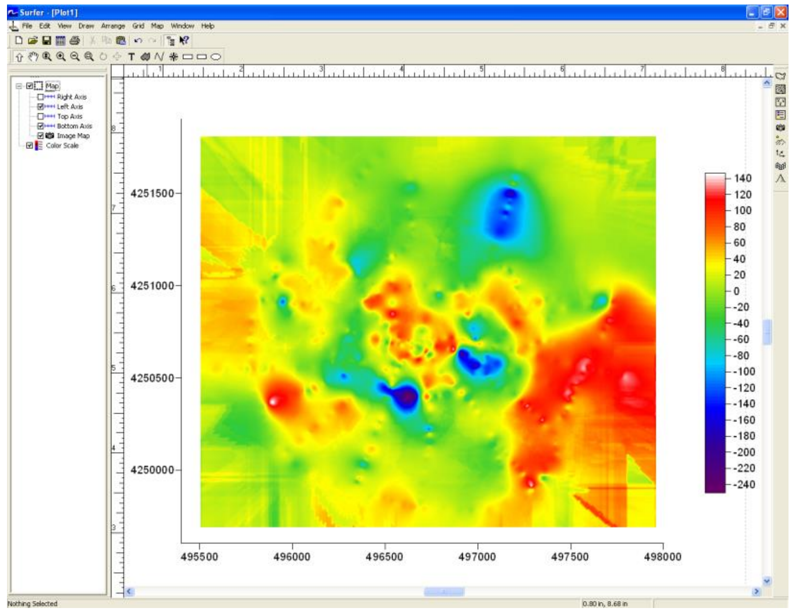
3.2- Create a SP map and enhance its presentation

The SP grid we created can be used to generate various types of maps. In this section, we will see the useful commands to create them and show some examples of the resulting maps. The process is described on the left and the result on the right:

(1) Create an Image Map

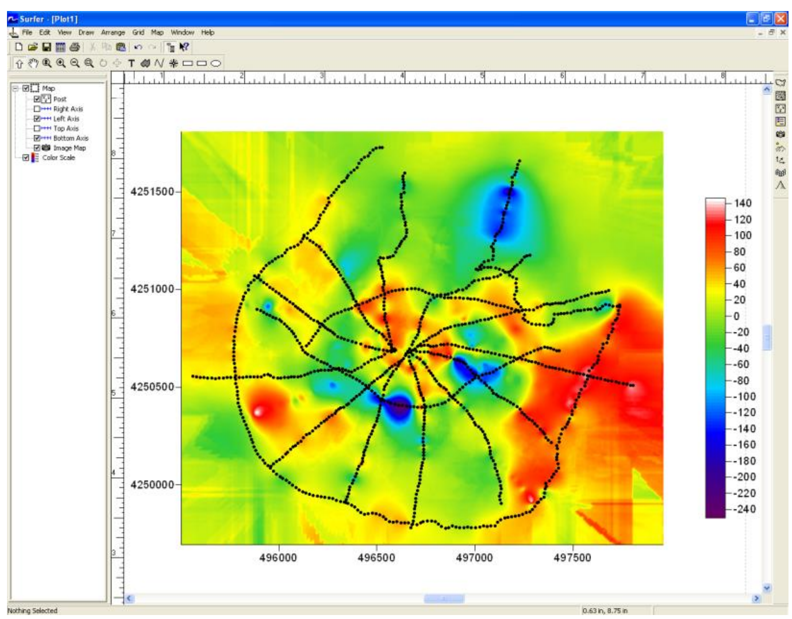
- Click on **Map | Image Map**
- Select, and open your grid with the window that just appeared
- The map is created.
- Double-click on the map to manage the **General** properties (**Color**, **Interpolate Pixels**, and **Show Color Scale** options)

If you click on the colour bar in the **Color** section of this properties window, you access to a new window where you can create your own colour scale or load an existing one (they are saved as .clr files). You can save your own colour scales.

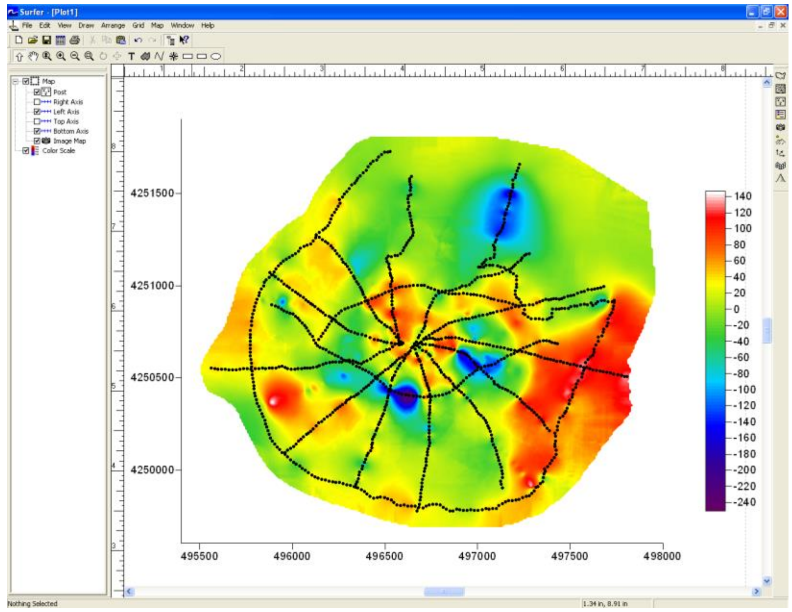


(2) Make your datapoints appear on the map

- Click on **Map | Post Map | New Post Map**
- Select, and open your data file (Excel or Surfer worksheet) with the window that just appeared.
- Double-click on the created post to manage the **General** properties (select the columns of the worksheet corresponding to the X and Y coordinates; select the symbol, etc…)
- Click on OK: you now see the post map and the image map into the main Surfer window. You can also manage them from the synthetic menu on the left.
- Select the post and the map together
- Click on **Map | Overlay Maps**



(3) Cut off part of the map



First, we must create a new grid adding nodes to the grid (⇔ adding points in the file). This will smooth the contours of the final map:

- Click on **Grid | Spline Smooth**
- Select your grid
- Select the following options: Insert Nodes; Number Nodes to Insert = 10 or more (make tests)
- Click on and choose a name and an emplacement for the smoothed grid.

Create a .bln file containing the contours of the area you wish to keep in the final map:

- Select the image map in the main window of Surfer
- Click on **Map | Digitize**
- On the image map, click to draw the contour of the area you wish to keep in the final map. The last point must be exactly the same than the first one (copy/paste the coordinates directly in the file).
- Save the .bln file from the little “digit.bln” window.
- Open the .bln file and change the number 1 in cell B1 to 0. This number decides if you blank the outer (0) or inner (1) part of the drawn area.

Finally we can blank the grid:

- Click on **Grid | Blank**
- Select your smoothed grid
- Select the .bln file just created
- Choose a name and an emplacement for the blanked grid you are creating
- Click on OK

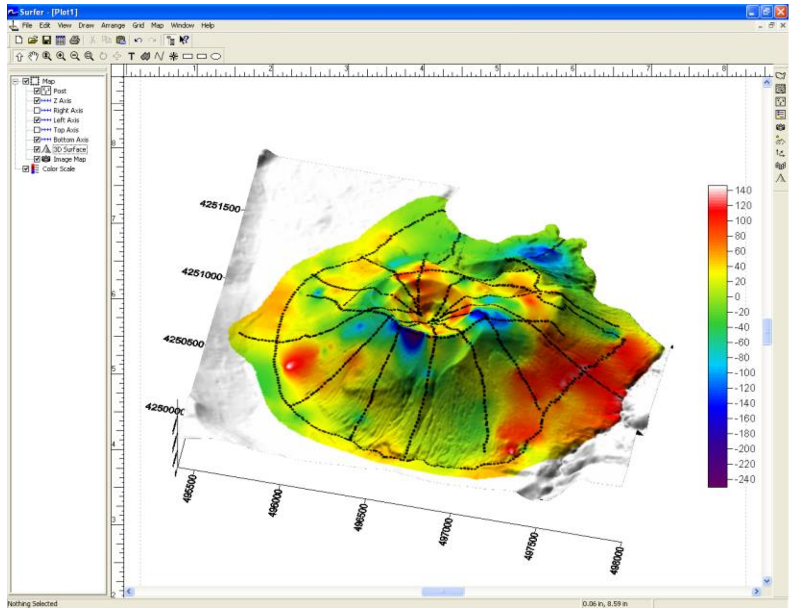
You can now create a new image map with the blanked grid and overlay it with a post map of the data (as described previously). Alternatively, you can modify the source-file of the image map that already exists (the one created in section (2)):

- Double-click on the image map
- In **General**, modify the **Input Grid** by clicking on and selecting the blanked grid you have just created.

(4) Overlay your map on a DEM

You can drape your SP map on a a 3D surface of the DEM (**Surface**).
- Use the **Map | Surface** command
- Select the grid file corresponding to the DEM of the study area

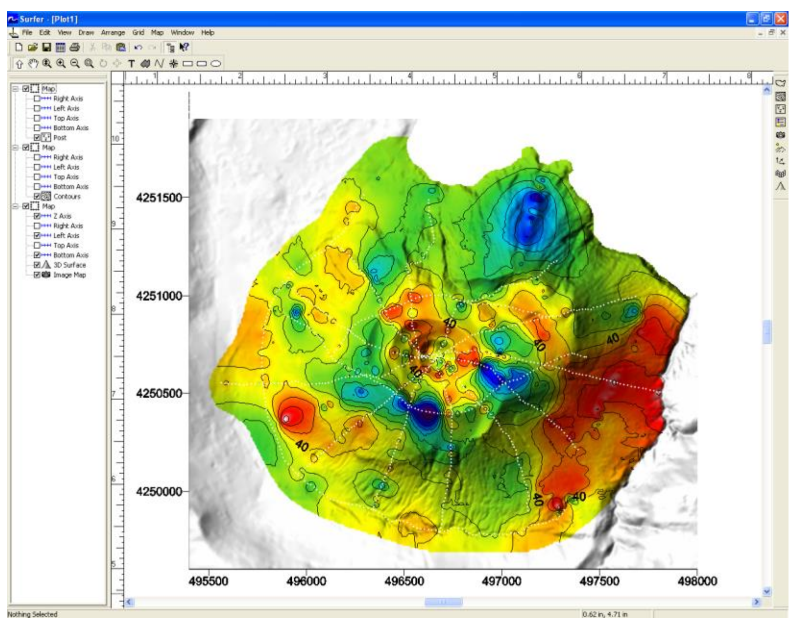
You can manage various appearance parameters by double-clicking on the DEM now created (lighting, Z-scale factor, etc…).
- Select the surface of your DEM and the image map of your SP in the main window of Surfer <u>or</u> in the Object Manager (list of the objects displayed in a tree view, on the left of your screen).
- Click on **Map | Overlay Maps**



(5) Create a contour map

Contour maps can help visualizing better the distribution of the SP anomalies highlighting the SP transitions, not ever easy to visualize with the color-scale. A second interest is to make possible visualizing the SP data overlaying the contour map on any kind of raster image (e.g. aerial photo, geological map, etc…).

- Use the **Map | Contour Map** command
- Select the grid file of your SP data and validate
- Overlay the contour map with the image map of the SP data already overlaid on the surface of the DEM and with white datapoints.



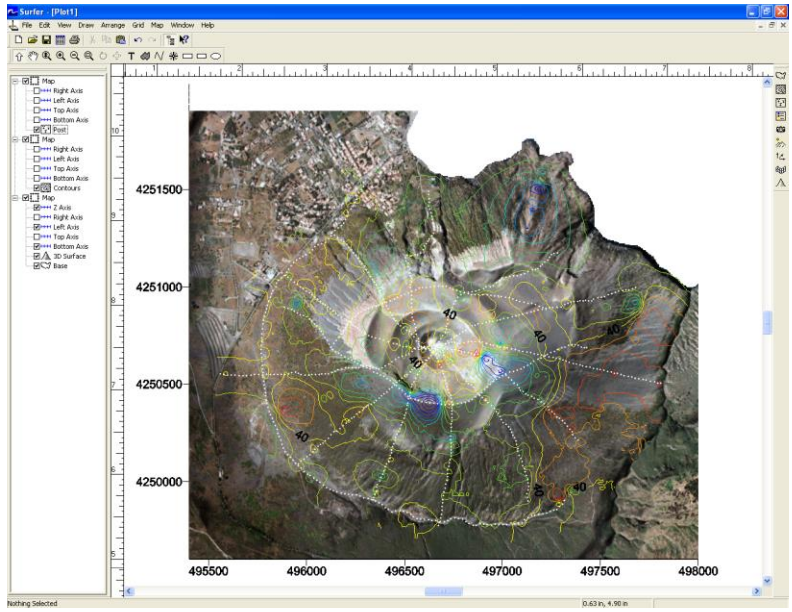
Overlaying the data on a raster:

- Create a contour map as shown before and modify the **Levels** properties (double-click on the contour map):

Click on **Line**, select **Gradational**, click on the **Color** bar and load or create a colour scale for SP data.

- Validate until all the Properties windows are closed.

- Use the **Map | Base Map** command to charge the raster (here an aerial photo) of your study area. You must know the GPS coordinates of the four corners of the photo.



- Double-click on this base map and in **Base Map**, set the **Image Coordinates** as a function of the corresponding GPS coordinates
- Click on OK
- Overlay the contour map together with the base map, the surface of the DEM, and with white datapoints.

Remark: *the **Overlay Maps** command sometimes gives a bad aspect overlaying contour maps or post maps on a shaded relief map or a 3D surface (blurry aspect). If this happens you can click-right on the contour map or the post map (on the left window of Surfer) and click on **Break Apart Overlay**. This will separate the selected map. You then can place it manually above the shaded relief map or the 3D surface (however, this excludes the possibility to change the orientation of the 3D surface.*

4- Additional useful commands

4.1- Extract part of a DEM

In order to extract part of a DEM, we will extract a section of a grid file to create a new grid containing only the section of interest.

(We suppose we are working with a DEM with coordinates in kilometers)

- Click on **Grid | Extract**
- Select the grid file from which you want to extract a new grid
- Create an output grid file: click on the  button to choose the filename and choose where you want to save the new file.

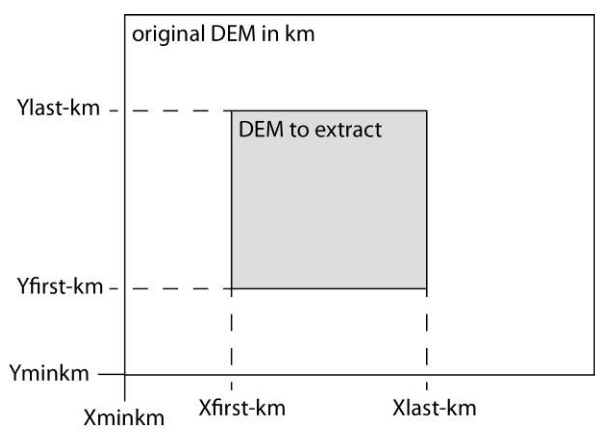


Fig. 4.1. Scheme showing the coordinates to use for the Grid | Extract process.

- Choose the GPS limits of the DEM to extract (X**first**-km, X**last**-km, Y**first**-km and Y**last**-km; see Fig 4.1).
Remark: *"last" and "first" are the terms used in the Extract Grid window (see Fig. 4.2)*

- Detemine to which nodes (X**first**-node , X**last**-node et Y**first**-node et Y**last**-node) the GPS coordinates are corresponding, applying the following formulae.
Xnode = ((Xkm – X**min**km)/spacing) + 1
Ynode = ((Ykm – Y**min**km)/spacing) + 1

with X**min**km et Y**min**km the "minimum" coordinates of the original DEM (⇔ bottom left end corner of the DEM; see Fig. 4.1). To see it, double-click on the original DEM in the main window and check the **Limits**; and for a 25 m DEM, spacing = 0.025 (km)

- Enter the four X and Y limits (just calculated in nodes) in the lower part of the window (see Fig. 4.2)
- Click OK

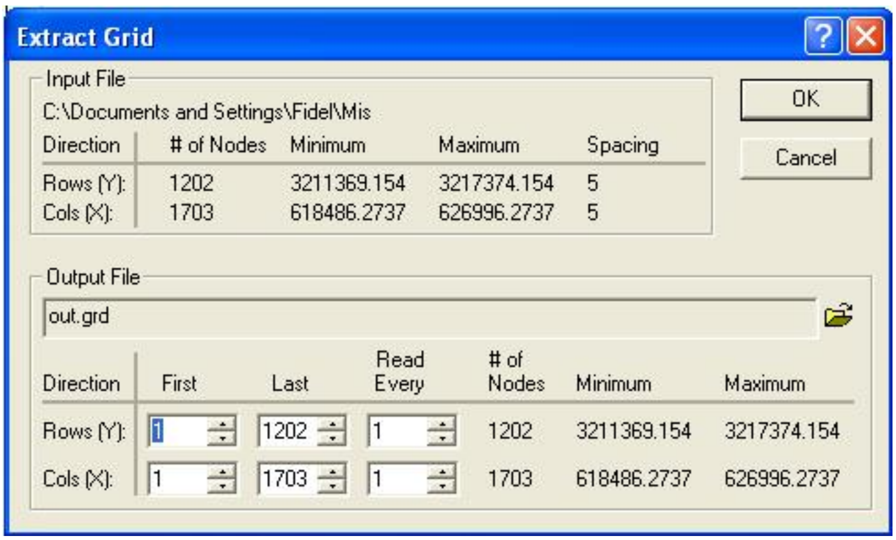


Fig. 4.2. Image capture of the **Grid | Extract** command.

4.2- Extract a profile

Surfer allows extracting a profile from any grid file. We can create topographic profiles from a DEM, SP profiles, temperature profiles, etc…

Example for a topographic profile:
- First, use the **Map | Shaded Relief Map** command to display the DEM in the main window of Surfer and select this map.
- Click on **Map | Digitize**
- In the main window, click on every point of the DEM necessary to trace the profile you want to extract (linear profile or not)
- Save the .bln file created
- Click on **Grid | Slice**
- Select the grid file of your DEM and validate
- Select the .bln file you have just created and validate

- Choose a name for your resulting .bln and .dat files (see the Surfer help **Slice** section for details on the files content)

To plot the profile:
- Click on **Map | Post Map | New Post Map**
- Select the .dat file just created and validate
- Double-click on the graph and select the X and Y coordinates (which should be columns D and C respectively) and validate.