Pymagra manual

Program for treatment of magnetic and gravity data

The program allows reading magnetic or gravity data with different formats:

- Geometrics « .stn » files for magnetic gradiometry data
- GXF format
- Simple text file with x,y,z,v(,v2), e.g. outputted by program mgwin.exe

Installation

Mouse

It is strongly recommended to use a mouse. The program needs the central mouse button (or wheel). If you are working with a touchpad, configure it such that it simulates the central mouse button. The simplest is certainly to configure a three-finger-touch as central button. For this, under Windows press the WINDOWS-Key+I. On the screen that appears, click on “Périfériques” (the English version may be "Devices"). There, on the left-side panel, search “Pavé tactile” ("Touch Pad" in English?). Scroll down until you see the image with three fingers. Below this image, under “Appuis”, change to “Button central de la souris” ("Central mouse button"?).

Installation is done with

pip install pymagra

Once installed, open an Anaconda Powershell window, cd to the folder containing the data file(s) and type:

pymagra followed by ENTER

This may be done also from any other command window (cmd under Windows) if the folder containing the executable is placed in the Path. In Windows, this path is C:\User\user_name\anaconda3\Skripts.

You may also open file pymagra_start.py (in C:\User\user_name\anaconda3\Lib\ site-packages\Pymagra) in a GUI like Spyder and run it from there. This gives the user the possibility to define a working directory at the beginning of pymagra (near line 18, search: “dir0 =” and change the given path), especially useful if you a working for several days with data in the same folder. If using Spyder, it is recommended to run the program within its own console: “Run -> Configuration per file -> Run with custom configuration -> Execute in dedicated console”.

Running

After starting the program, the user is asked to choose the data file to be treated. By default, the program proposes files with extension .stn (Geometrics data), .gxf, .xyz or .dat. If the file name has a different extension, click in the extension selection and choose “all” to see other files. Extensions may be in capitals or not. For the moment, only .out is accepted as additional valid extension. For the corresponding data formats, see appendix. If your data have one of the valid data formats but not the expected extension, just change the file extension.

Once the file chosen, different dialogue windows open:

1) Data types: choose whether the file contains magnetic or gravity data
2) Geometry parameters:

   The contents of this dialogue box depend on the data type. For .stn and .dat files, if they are tagged as magnetic data, the program supposes gradiometer data and asks for the following inputs:

   - Height of sensor connected to channel 1 above ground [m]
   - Were the two sensors placed vertically or horizontally?
   - Distance between the two sensors [m]. For vertical disposition, a positive distance implies that the sensor connected to channel 2 is above the one of channel 1 and a negative distance the reverse. For horizontal disposition, a positive distance means that the sensor connected to channel 2 is placed to the right of channel 1 in the direction of movement a negative distance means the reverse.
   - The coordinates of the data stored in the file are mostly local coordinates and the lines may not have been measured in N-S direction. In this case, you may give the direction of the local Y coordinates with respect to magnetic North (measured in degrees, positive from N to E). This direction will be indicated on all maps and is used for certain data treatments (reduction to the pole) and for inversion.

   If data are in gxf (.gxf) format, only one sensor per file is accepted. In this case, only the height of the sensor and the direction of the Y coordinate with respect to magnetic N (for magnetic data) or geographic N (for gravity data) is asked for.

   For BRGM flight files (.xyz) this dialogue box is not opened since all necessary information is given within the file.

3) Earth's magnetic field data: If the file contains magnetic data, a further dialogue box is opened asking for the local inclination and declination of the Earth's magnetic field measured in degrees.

The data are then read and displayed in a full-screen window (Figs. 1 and 2). In addition, the program searches for a file called "lineaments.dat" which, if it exists, contains magnetic or gravity lineaments picked in former runs of pymagra. These lineaments are by default plotted onto the data map, but the plotting may be switched off later-on (see menu Display).

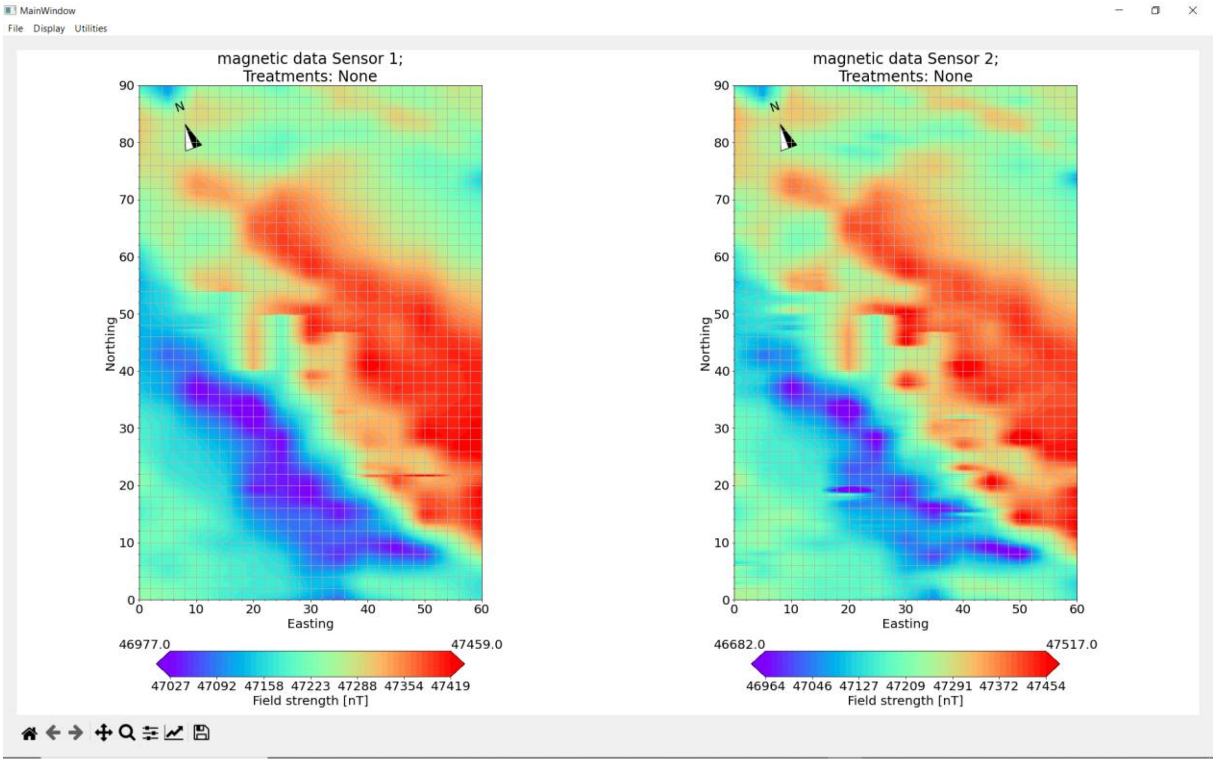

Fig. 1: Screen copy of the main screen with gradiometer data. Lines were measured in direction N20°E

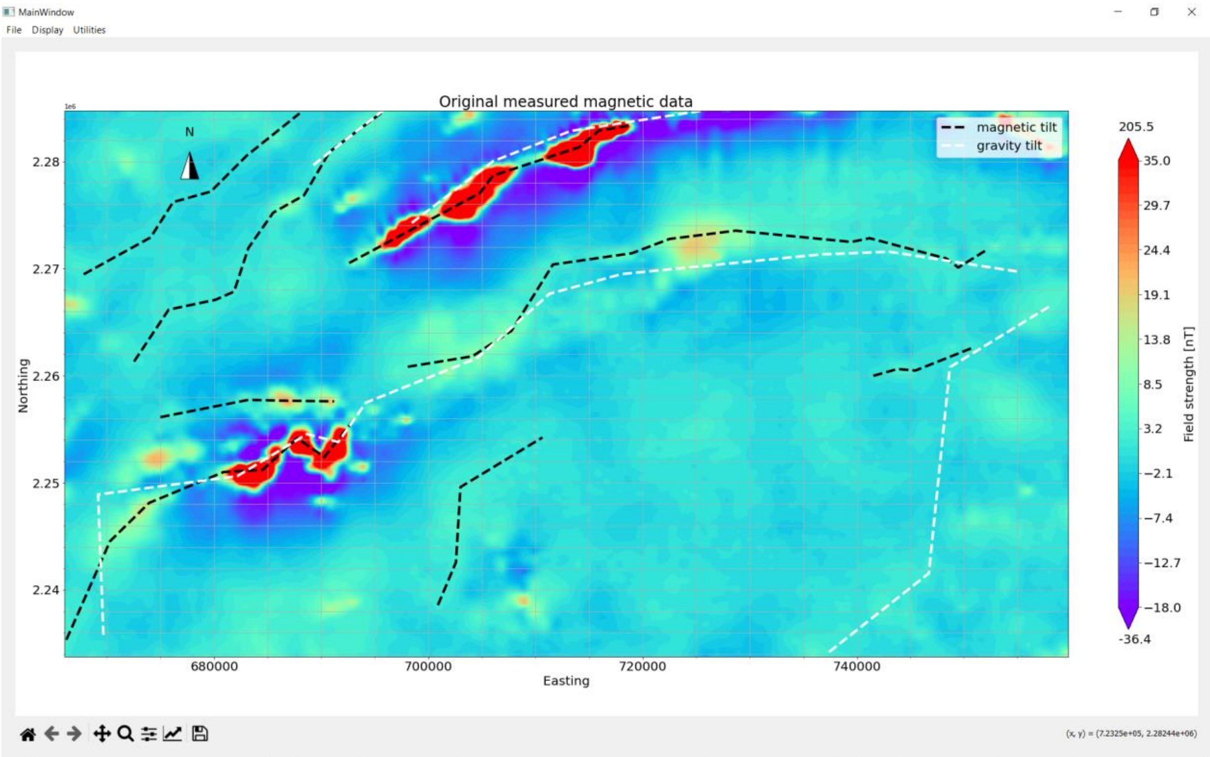

Fig. 2: Screen copy of the main screen with .gxf data and measured lineaments.

The following treatments may be used:

1. Correction of diurnal variations for magnetic data (gravity data are supposed to be already corrected).
2. Data clipping and muting to eliminate measurement errors (again, mainly for magnetic data).

3. Reduction of directional effects in magnetic data.
4. Interpolation onto a regular grid, filling also internal gaps.
5. Extrapolation in order to create a full rectangular grid for use of FFT.
6. Pole reduction for magnetic data.
7. Vertical field prolongation.
8. Application of Spector and Grant method of spectral depth determination.
9. Tilt angle calculation of picking of lineaments.
10. Calculation and inversion of analytic signal.

In general,.stn or .out files do not contain gridded data. Also gxf, though it is a format for gridded data, may contain holes. Therefore, before applying some of the treatments (especially those from 5 to 10), data should be interpolated onto a regular grid. However, before gridding, diurnal variations and directional effects should be eliminated. Gridded data are no longer associated to measurement times, which makes reduction of diurnal variations impossible and they are also no longer associated to original lines and therefore measurement directions and therefore directional effects can no longer be reduced. Data clipping is possible on gridded data; however, it is better done on the original ones in order to avoid negative effects on interpolation.

Once data are interpolated all following treatments are done on the interpolated data. It is, however, possible to return to the original data, losing all treatments, and restart (see menu Utilities).

Menus

File

Choose additional data files (keyboard shortcut: SHFT-D)

ATTENTION: this was programmed for an older version of pymagra. In the actual version, this point is not tested and will most probably make the program crash…

Allows adding additional data to the ones read in the beginning of the program. Attention, if any treatment has been done on the data read before, those data should be reset to the original values (see menu Utilities) before reading new data, since new data are added to the actual (i.e. potentially treated) data set. All files must have data measured in the same direction and with the same line spacing (not necessarily the same spacing along the lines). If the blocks are continuous within the measurement direction, the data should have been acquired on the same lines (not all lines must be occupied in both blocks, but, e.g., it is not allowed that in block 1, line coordinates are [0, 1, 2] m and in block 2 [0.5, 1.5, 2.5] m).

Save magnetic data .stn format (keyboard shortcut: S)

Save (eventually treated) magnetic data to Geometrics .stn format.

Save .dat format (keyboard shortcut: F)

Save (eventually treated) data to simple text format, used by program mgwin.exe. This file has one header line, followed by one line per data point: X, Y, Value (optionally: second sensor value, vertical gradient). The format corresponds to the one exported by Geometrics magmap program to Surfer format.

Get base station data (keyboard shortcut: SHFT-B)

Read base station data from file in Geometrics .stn format. The program only reads those data and plots them onto the screen in a floating window (Fig. 3), allowing interactive editing, but it does not do the base station correction (see menu Utilities). If file contains erroneous data (spikes, noise…), one may choose segments to be cut out by clicking beginning and end times with mouse wheel (Fig. 4). Right click within the plot window closes the base station window.

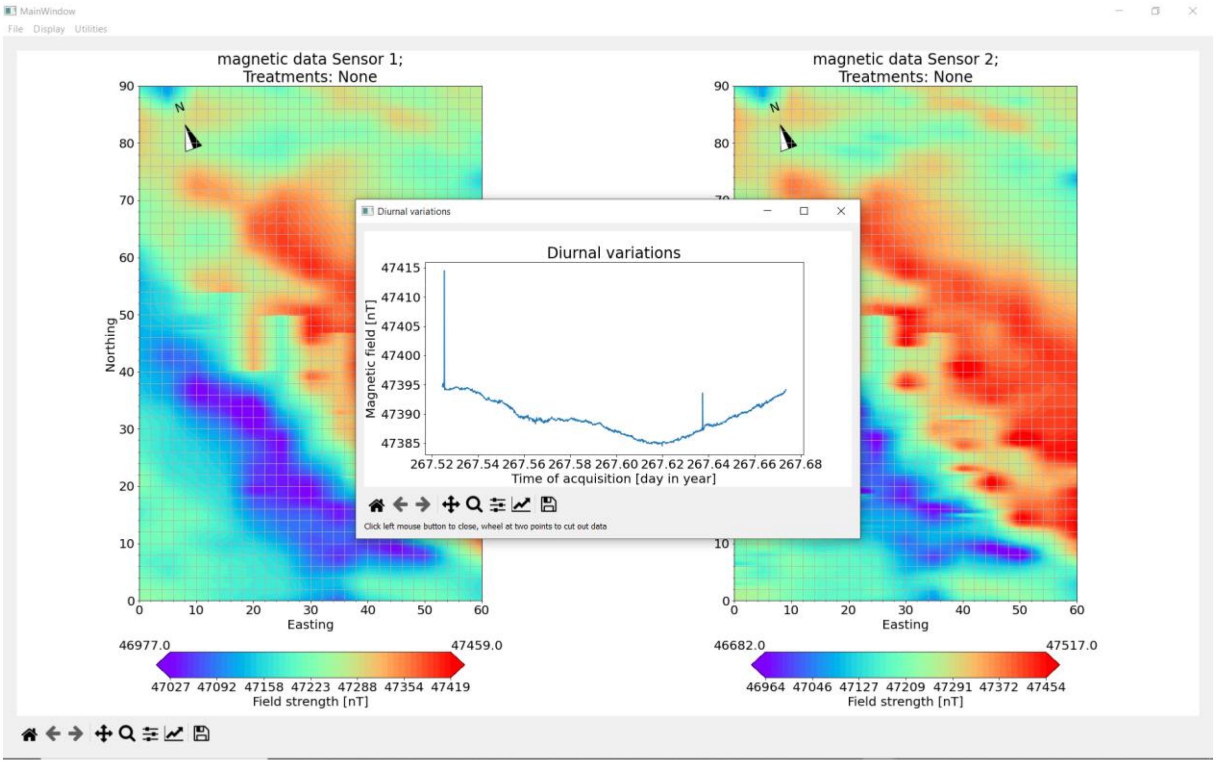

Fig. 3: Plot of read base station data with spikes.

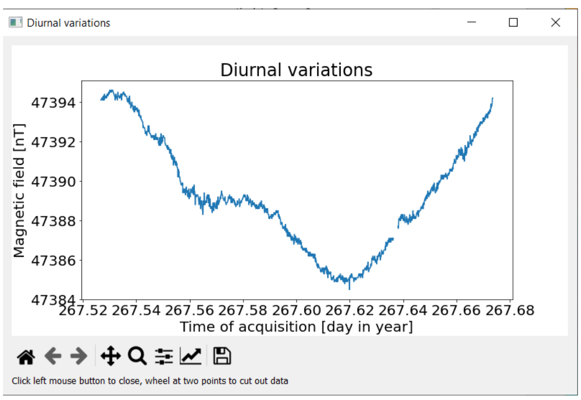

Fig. 4: Base station data having cut out the two spikes.

Save base data (keyboard shortcut: CTRL-B)

Save magnetic base station data to Geometrics .stn format. This option is mainly used in two situations: Or base station data were edited, or if no base station data were measured, but they were estimated from the measured field data using medians of the lines (see menu Utilities).

Save plot (keyboard shortcut: SHFT-P)

Save plot of main window into png file. The file name contains the date and time of file creation.

Get geography data (keyboard shortcut: SHFT-G)

Read geography and geology data to be plotted onto the maps (Fig. 5). The file is chosen interactively and has the following format:

Keyword (may be "#LINE", "#POINT" or "#END"; the first letter of Keyword is the hash tack)

If "POINT" one line follows with:

x y text

If "LINE", one line follows for every point defining the line:

x y

The file must be finished with a line containing #END in the first four columns

Usually, points are towns and text the name of the town. x and y must be given in the same coordinate system as the data. If lines limit a closed surface, the last point must be equal to the first one.

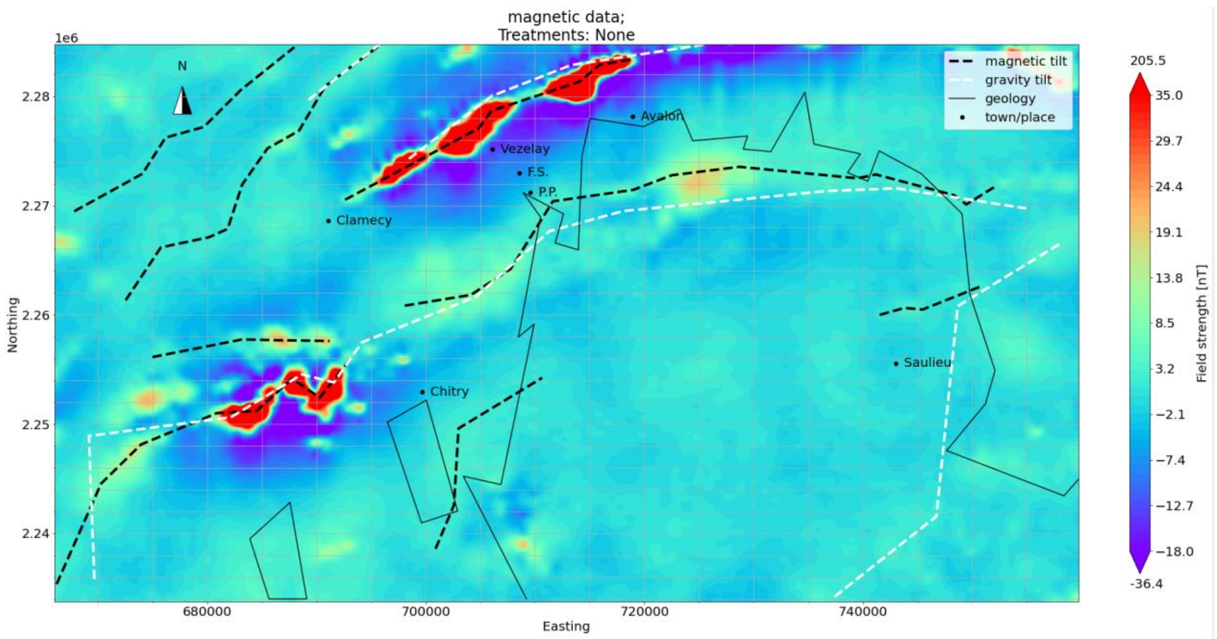

Fig. 5: Magnetic data with lineaments and geographic/geologic information

Quit (keyboard shortcut: CTRL-Q)

Finish program, the user is asked for confirmation.

Display

Plot original data (keyboard shortcut: O)

Plots the original (read) data. This does not reset the actual data arrays to original data. In the beginning of the program, a backup copy of the data is made. This backup is plotted. Further treatments continue to be done on interpolated data.

Plot treated data (keyboard shortcut: D)

Plots the treated data (actual data array). This option is only useful after having used option Plot original data.

Plot single line (keyboard shortcut: L)

Waits for a mouse click and plots the line nearest to the mouse click (Fig. 6). In the shown window, it is possible to mute data. For this click on the mouse wheel ones inside the axis (coordinate system) to choose the beginning of the section to be muted and a second time for the end of the section to be muted. This procedure may be applied several times. Clicking the right mouse button inside the axis shows the next line to the right of the actual line (i.e. larger coordinates: to the East if lines were measured in N-S direction or to the North, if lines were measured in E-W direction). Clicking on the left button inside the axis goes to the next line in the other direction. Clicking any mouse button outside of the axis (outside of the coordinate system) closes the window and returns to the main window.

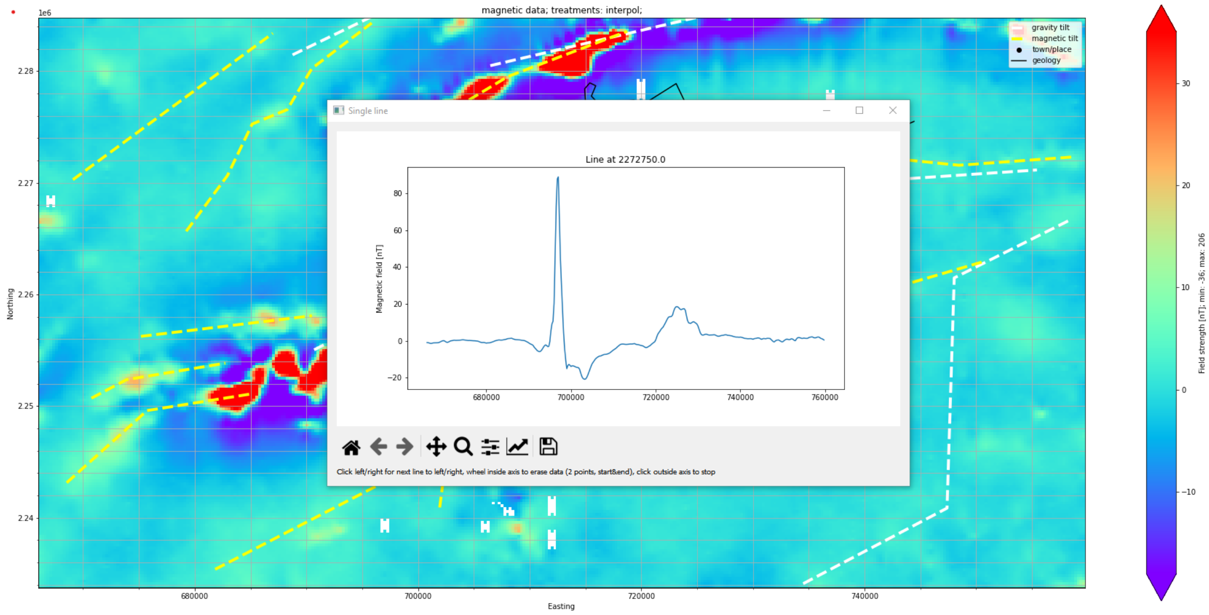

Fig. 6: Example of line plot

Plot base station data (keyboard shortcut: B)

Plots base station data (read or calculated, see menu Utilities->Apply diurnal correction). The time is given in seconds since the beginning of the year of measurement or, if this information is not available, in seconds from the first measurement. It is possible to mute erroneous data interactively in the new window. For this, click on the mouse wheel at the beginning and the end of the section to be muted. This may be done several times. A click with the right mouse button closes the window and returns to the main window.

Plot medians (keyboard shortcut: M)

Plots the median values of all lines (Fig. 7). The points are coloured as function of the sensor used in case of gradiometer data and as function of line direction (useful mainly for magnetic data having been measured in go and back directions). Any mouse click closes the window.

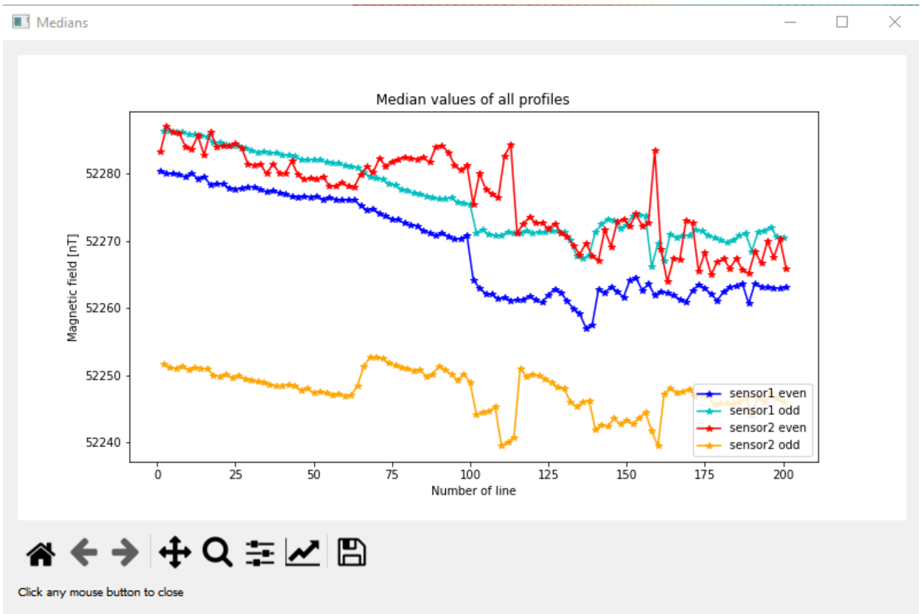

Fig. 7: Example of median values of gradiometer data measured in two directions.

Plot gradient (keyboard shortcut: G)

If gradiometer data are displayed, it is possible to show only the data of the two sensors or the two sensors and the gradient (Fig. 8). This option toggles between the two options.

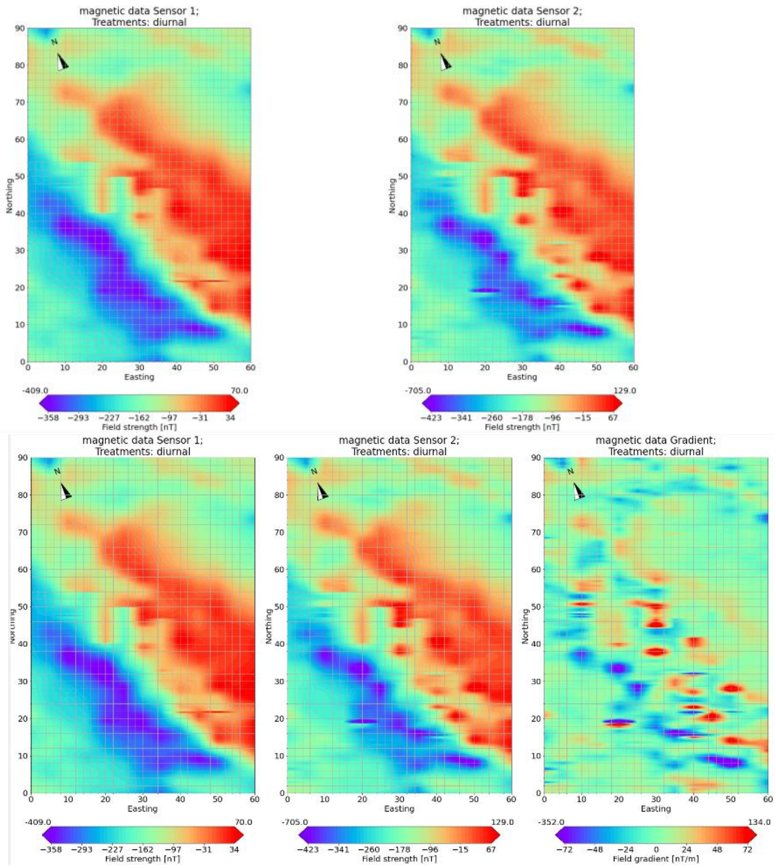

Fig. 8: Example of gradiometer data. Top: Maps of the two sensor data; Bottom: maps of the two sensors and the gradient.

Plot geography (keyboard shortcut: CTRL-G)

If geography data were read (see menu File), this option toggles between displaying them or not.

Plot grid (keyboard shortcut: X)

Option toggles between showing or not grid lines of the minor ticks onto the maps.

Plot lineaments (keyboard shortcut: SHFT-L)

If lineaments were measured in this session or reading file lineaments.dat, this option toggles between displaying them or not.

Zoom

The different zoom options are not yet implemented. For the moment, the zoom should be done using the icon in the QT toolbox at the bottom of the screen. It is, however, not permanent and applies only to one subplot.

Change color scale (keyboard shortcut: Q)

By default, the color scale is constructed such that its lower end corresponds to the quantile 0.01 (the lowermost 1% of the data are clipped) and the uppermost to 0.99 (the upper most 1% of the data are clipped). This option allows changing this by setting a new overall quantile (valid for all sensors and the gradient) for clipping or by defining fixed upper and lower limits for each sensor and gradient separately. This allows, e.g., fixing a color scale for comparison of different maps. If fixed limits are given and the upper and lower limit are different, these limits have preference over a given quantile. If quantile is zero and fixed limits are both the same (usually both 0), the color scale limits correspond to the data limits for every sensor independently.

Every second line (keyboard shortcut: 2)

Plot only one line out of two. This is useful if a strong directional effect is visible in magnetic data. The user is asked whether odd lines or even lines should be plotted (natural counting, i.e. first measured line is considered odd number). Clicking again on this option allows or plotting the other line direction of all lines again.

Utilities

Restart with original data (keyboard shortcut: CTRL-R)

In contrast to the option Plot original data (menu Display), this option undoes all applied treatments and replaces the actual data arrays by the backup arrays. All preparative treatments (e.g. diurnal variations of interpolation) will have to be done again. The program does not allow partial undo of operations.

Apply diurnal correction (keyboard shortcut: CTRL-D)

If diurnal corrections were read from a file, subtract measured base station data from field data. If no base station data exist, a polynomial is fitted to the medians of the first sensor. The user is asked for the degree of this polynomial. In addition, if data have been measured in several blocks (e.g. at different days), the program searches for common points within the different blocks and adds as constraint a minimum difference between the common points after application of the diurnal variations calculated in this way. The relative weight of fit of medians and fit of common points may be defined interactively. **TODO**: This option has not yet been tested! Its working is linked to the working of menu File -> Choose_additional_data_file.

Clean data (keyboard shortcut: CTRL-K)

Possibility to mute data by defining different quantiles or different fixed values for the upper and lower data limits. In contrast to the option Change color scale (menu Display), this option set the values outside the defined limits to nan. The limits may also be defined on a histogram. The same limits are used for both sensors.

Reduce direction effect by median (keyboard shortcut: CTRL-M)

The directional effect of magnetic data is reduced by setting the median of every second line to the average value of the medians of the two adjacent lines (for lines at the edges, the same median value as the neighbouring line is used). The user may decide whether to change the medians of the odd lines or those of the even lines.

Reduce direction effect by Gauss (keyboard shortcut: CTRL-G)

See Masoudi et al., J. Geophys. Eng., 2023. The adjustment may be done on the odd-numbered lines or on the even-numbered ones (natural counting, first measured line is odd). In addition, the histogram adjustment may be done globally, i.e. all odd vs all even lines, or line by line, i.e. the histogram of a line is adjusted to the combined histogram of neighbouring lines. In the actual version, data must be interpolated on a regular grid. Do this interpolation such that in the cross-line direction, the sampling step is equal to the line distance.

Interpolate (keyboard shortcut: CTRL-I)

This option interpolates data onto a regular 2D grid parallel to the measurement lines. The user is asked for the interpolation step dx and dy parallel to the local coordinate system. For each line, the positions of the first and last measurement are searched and interpolation is limited to the area between these measurement points, rounded to the next multiple of the corresponding sampling step. In a second pass, interpolation is done in the sense perpendicular to the measurement direction with data spacing equal to line spacing. In this way, if there are missing values at the beginning or the end of certain lines inside the measurement area, they will be interpolated. However, missing points at the edges of the area (which do not have neighbouring data on both sides in the measurement direction and in the opposite direction), are not extrapolated. I.e., a convex zone of data is created, presenting possibly zones without data in the corners.

Fill rectangle (keyboard shortcut: CTRL-F)

Extrapolate data in the corners in order to fill the full rectangle with values. Nearest neighbour algorithm is used with squared distance weighting.

The following figures 9 to 14 show a typical sequence of data treatment for data without base station and a strong directional effect.

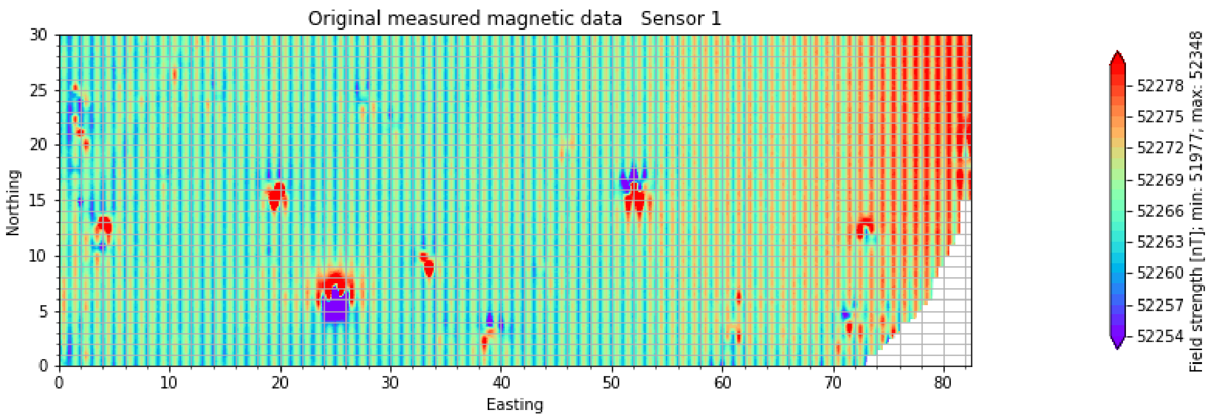

Fig. 9: Original data

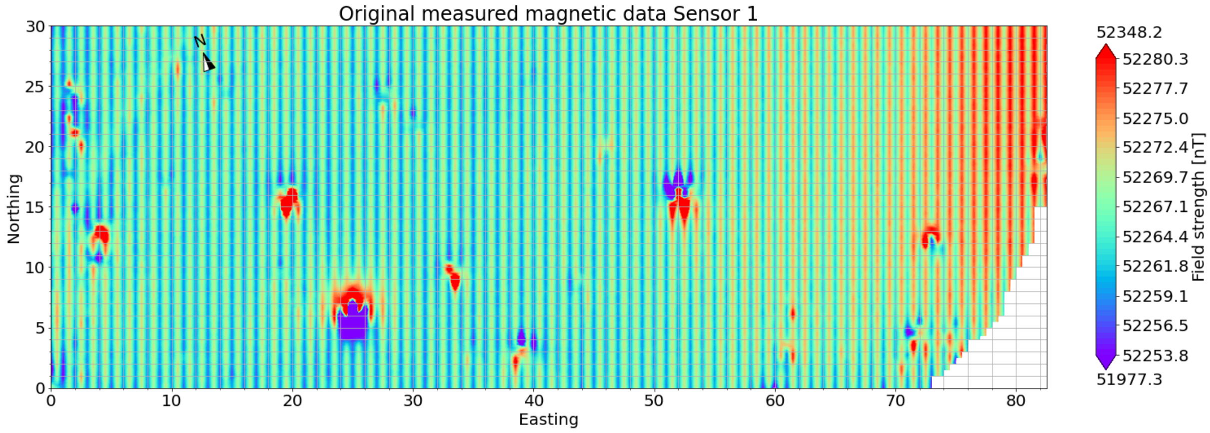

Fig. 10: Data after elimination of directional effects by median adjustment

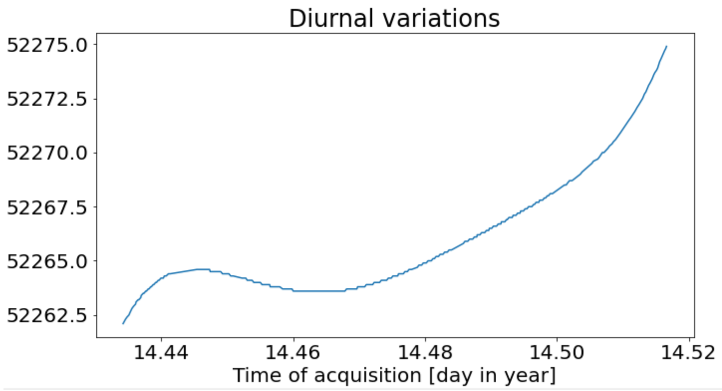

Fig. 11: Estimation of diurnal variations based on fitting a polynomial of degree 5 to median values of lines

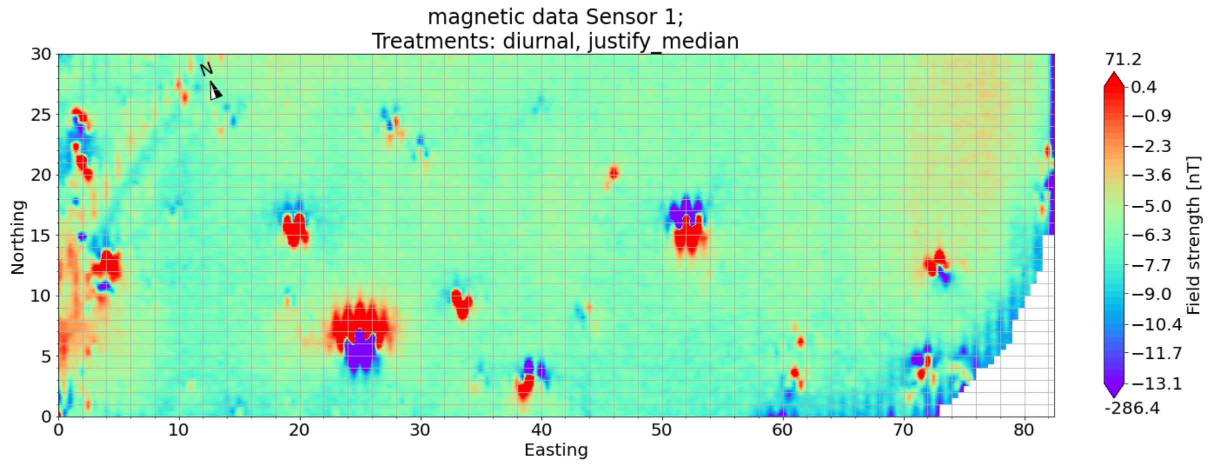

Fig. 12: Data after elimination of directional effects and elimination of diurnal variations

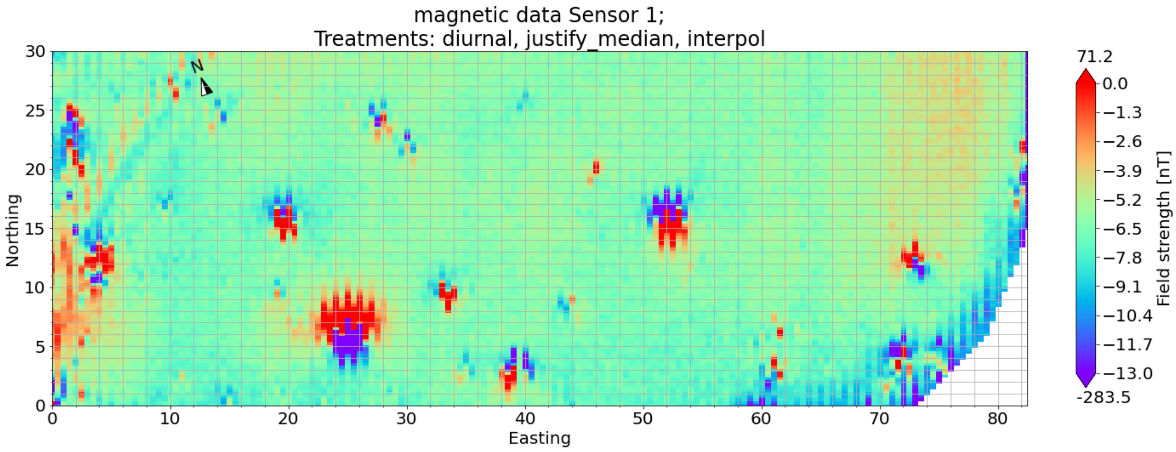

Fig. 13: Data after former treatments interpolated on regular grid (hardly any visible difference with Fig. 12)

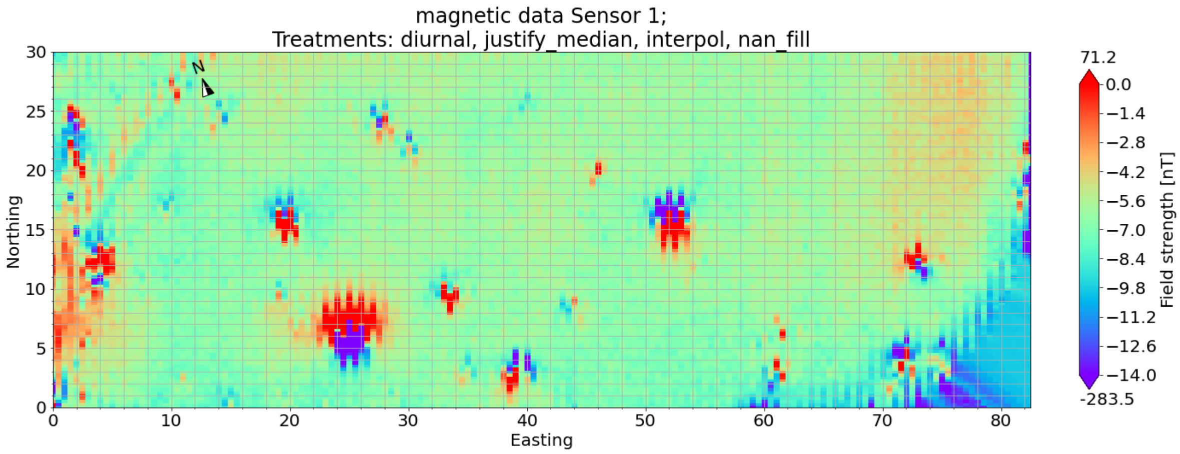

Fig. 14: Data grid filled with extrapolated values in the SE corner

Pole reduction (keyboard shortcut: CTRL-P)

Data are reduced to pole (Fig. 15). Algorithm considers only direction of Earth's field, i.e., magnetization is considered to be parallel to Earth's field. Earth's field direction had been given when starting the program. After pole reduction, the values that were nan before application of "Fill rectangle" are set again to nan.

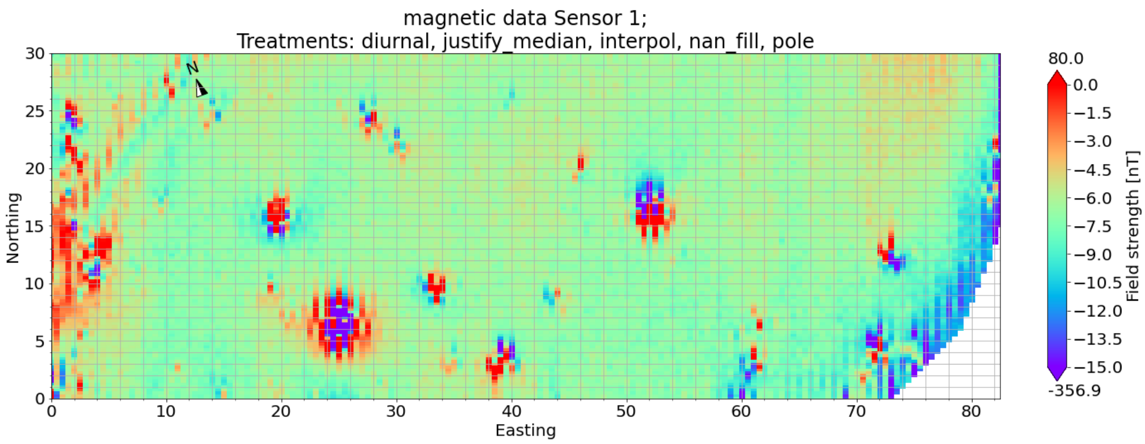

Fig. 15: Data after treatments reduced to pole

Upward continuation (keyboard shortcut: CTRL-U)

Data are upward continued by a user given distance (Fig. 16). Downward continuation is also possible by giving a negative distance, but it becomes rapidly unstable. If the value (given in meters) is positive, data are continued upward, if it is negative, continuation is downward.

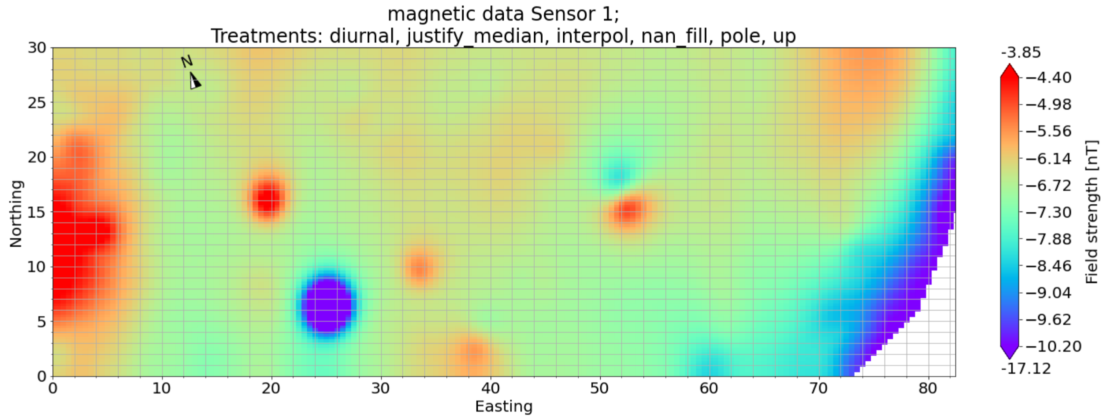

Fig. 16: Reduced to pole filed upward continued by 2m

Tilt angle (keyboard shortcut: CTRL-T)

Calculate tilt angle (Fig. 17) and search maxima of its gradient (Fig. 18) (Miller & Singh, JAG, 1994). In addition, program plots first and second vertical as well as horizontal gradients.

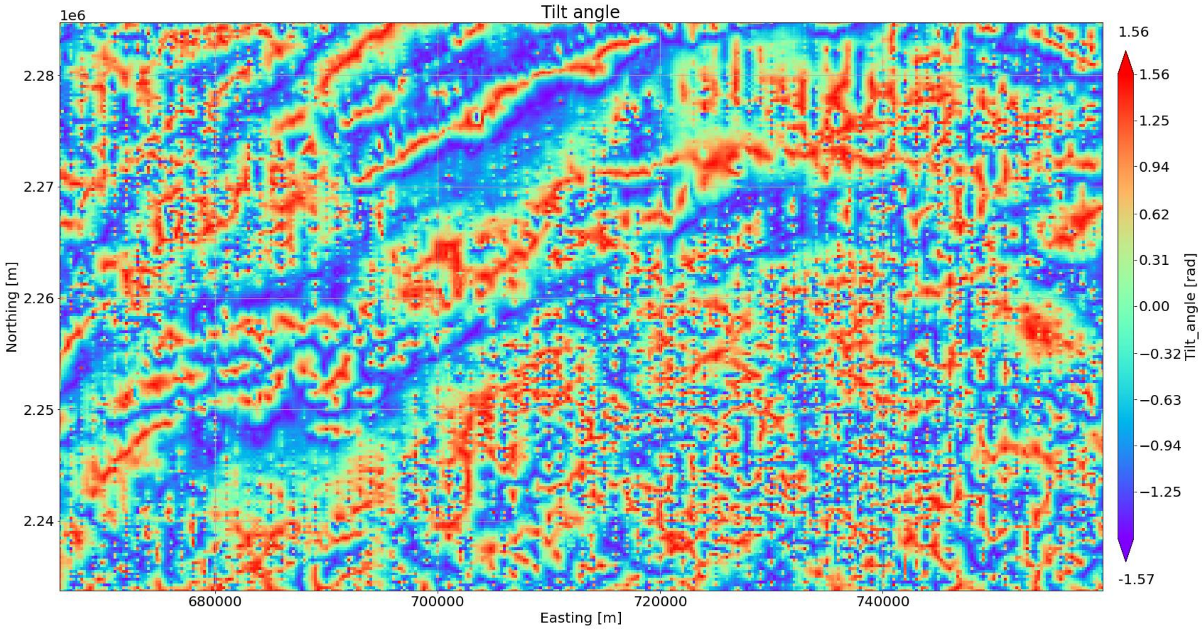

Fig. 17: Tilt angle of data shown in Fig. 2

Once the tilt angles are calculated, its values are smoothened with a 2D Gaussian filter with a size of 5 cells, the absolute horizontal gradient is calculated and local maxima are determined with a half-width of 3 cells (i.e. a maximum is found if the value at [i,k] is larger than all values of the next 3 cells in x and y directions. These maxima are plotted on a third figure, which appears on top of the other two, hiding them (Fig. 18):

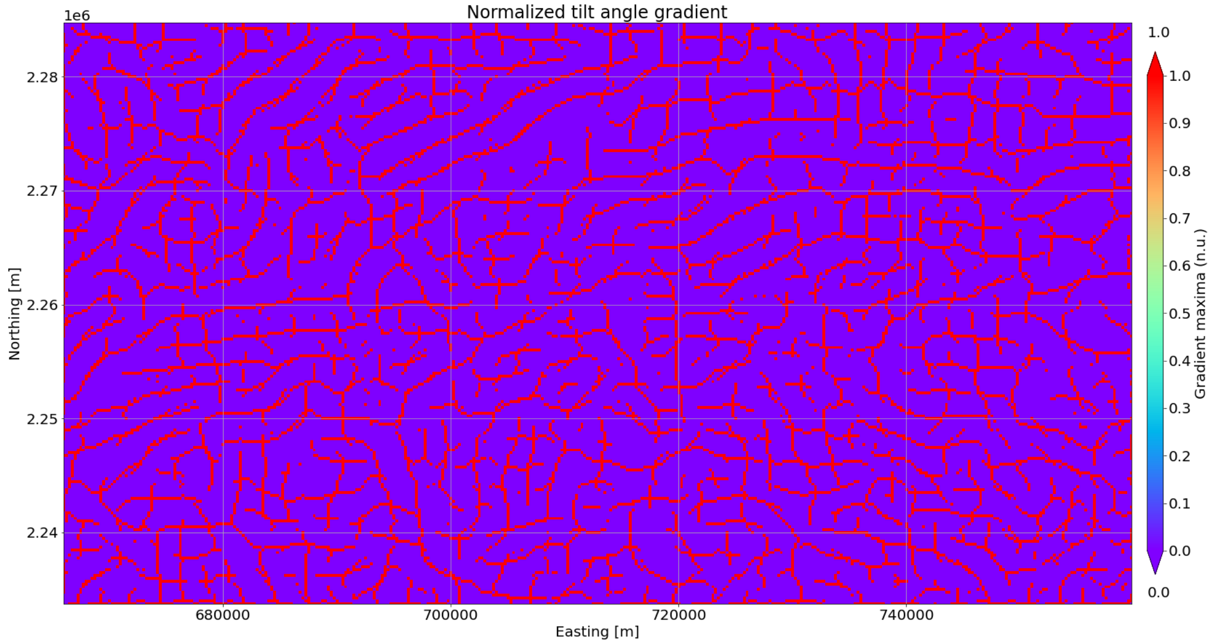

Fig. 18: Maxima of tilt angle gradient of data shown in Fig. 2

On the resulting map, lineaments may be visible and may be traced. For this, left click the points defining a lineament and finish line with a right click (position of right click is not considered to belong to the lineament). You may continue choosing further lineaments. A right click not preceded by a left click finishes picking and returns to the main window. A click with the mouse wheel searches the nearest traced point and erases the corresponding lineament.

The measured lineaments are written into file “lineaments.dat” and are displayed on all maps, if this option is not disabled in menu Display. Depending on the data type used for tracing a lineament, different names are associated to it, stored with the coordinates in file lineaments.dat and are used for legend on the maps.

Analytic signal (keyboard shortcut: CTRL-H)

Calculate analytic signal along measurement lines (Nabighian, Geophysics, 1972) and plot a map with these analytic signals. The results are given with respect to the Earth’s surface (it is supposed that the “height of lower sensor” asked for when starting the program is the height above ground and all subsequent treatments (upward continuation, return to original data) are added to this height). On the map, a left click triggers interpretation of analytic signals along N-S lines, a right click along E-W lines and a wheel click finishes the module. If solutions were found, they will then be stored in file “Analytic-signal-solutions_*dir*-lines.dat” where *dir* is “N-S” or “E-W” depending on the chosen direction of interpreted lines. The line nearest to the click will be shown later in an extra window.

In a next step, the lower part of the cumulative sum of all analytic signal data is shown and the user should click at the value below which the signal is no longer interesting (threshold). Typically, there is a large number of very small values and only in the order of 1% or so data are useful. Then, the chosen line is shown with the solution. A click into the window closes it and all solutions are shown on the map of the analytic signal. If the user estimates that not enough or too many solutions were found, it is possible to restart with a click on the map of the analytic signal.

Next, the user has the possibility to change manually the threshold (e.g. to maintain the same one if the calculations are done in both directions) and to indicate the maximum and minimum accepted depths. These depths are given with respect to the Earth's surface. It is thus possible to eliminate all results above ground and the maximum height may mainly limit the color scale for plotting the results (a few of the results are often quite large and don't make geological sense).

The inversion of the analytic signal for depths is done as follows: the local maxima along a line for all values above the threshold are searched from every maximum, the program searches to both sides or the first value below the threshold or the next local minimum. The so found data are used for inversion. A regression line is calculated for the equation y =a*x+b where y = 1/analytic_signal, x=(x-x0)**2, a = 1/alpha**2 (see Nabighian) and b=(depth/alpha)**2.

x0 is the location of a body limit. This position is located at the position of the maximum of the analytic signal. Since the maximum does not necessarily coincide with the maximum of the calculated signal, x0 is varied between the position of the measured maximum plus/minus dx/2 (dx being the sampling step in the direction of the line). In addition, the data are weighted by their squared value so that the highest values should be better fitted than small values. The values x0, alpha and depth giving the best fit to the data around every maximum are stored.

Spector 1D (keyboard shortcut: SHFT-F)

Calculate spectrum of all measured lines and determine automatically depth of sources (Spector & Grant, Geophysics, 1970). The user is asked for the direction of line extraction (by default the one of the measurement direction) and the half with for the determination of the local maxima along the spectra. This value determines the distance over which a value must be larger than neighbouring ones (1 means it is larger than the immediate neighbours on each side; 2 means it is larger than the two next samples on each side…). The slopes of the logarithmic spectrum, which are proportional to the depths of source rocks are calculated using these local maxima and give the average depth for the whole line. Two lines are fitted to these maxima, allowing for a break in slope. The program shows the results of all lines in a common plot (Fig. 19).

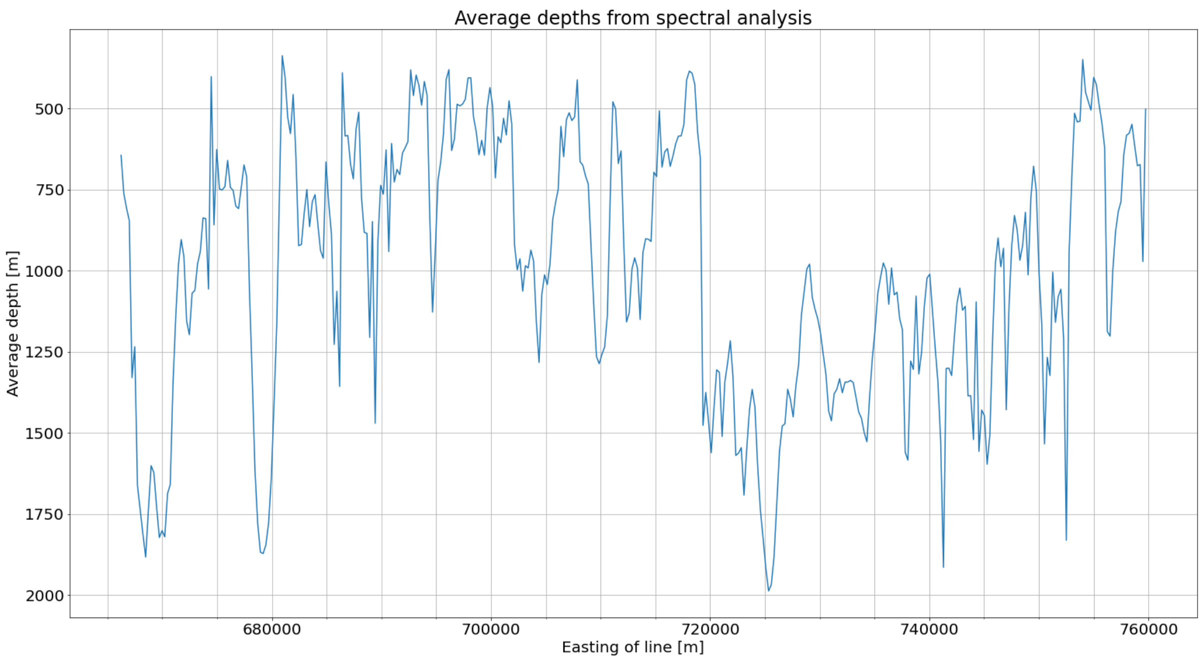

Fig. 19: Example of depth inversion results using line spectra (data of Fig. 2).

The automatic fits are not always satisfying, especially if the data would need at least three different slopes. Therefore, the user may now click with the left mouse button on one point of the results. The spectrum of the line nearest to the clicked position will show up (Fig. 20) and the first slope may be modified manually by clicking at the beginning of the line with the right mouse, pulling the line and releasing the mouse button at the end of the desired slope. The depth is immediately corrected in the plot of the results. This procedure may be applied to as many lines as desired. A right click within the results plot finishes the procedure and returns to the main window. The resulting depths are then stored into file “spector.dat”.

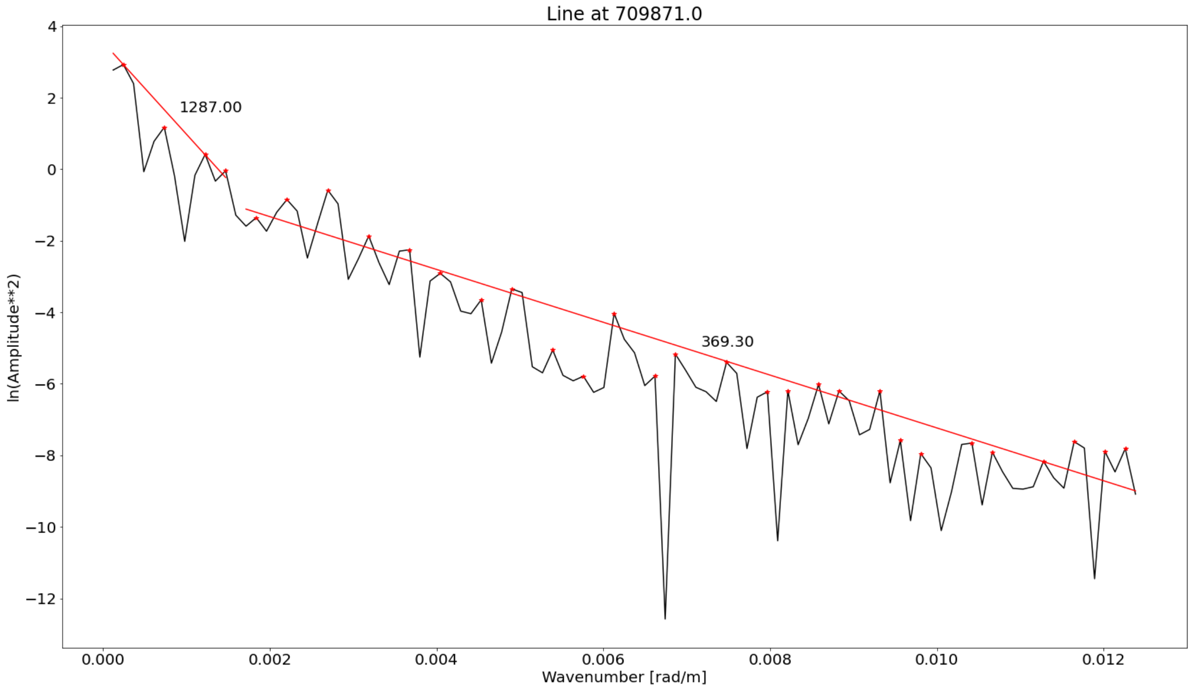

Fig. 20: Example of line spectrum in black with automatically fitted slopes in red. The red asterisks are used for line fitting. The best breaking point is in this case located at wavenumber 0.008 rad/m. The numbers written at each line are the calculated depths in meters.

Spector 2D (keyboard shortcut: ALT-F)

Calculate spectrum moving windows along all measured lines and determine automatically depth of sources (Spector & Grant, Geophysics, 1970). The user is asked for the window length (default is ¼ of the shortest dimension), the step size of calculation points (default is calculated such that the number of points to be calculated is about 500 to limit the calculation time) and the half with for the determination of the local maxima along the spectra. This value determines the distance over which a value must be larger than neighbouring ones (1 means it is larger than the immediate neighbours on each side; 2 means it is larger than the two next samples on each side…). The slopes of the logarithmic spectrum, which are proportional to the depths of source rocks are calculated using these local maxima and give the average depth for the whole line. Two lines are fitted to these maxima, allowing for a break in slope. The calculation is done twice at every point: once for data in N-S direction (half of the window width to the south, half to the north of the calculation point) and once in E-W direction. The retained depth is the average of the two results. The results are plotted as map with pixels centred on the data points (Fig. 21).

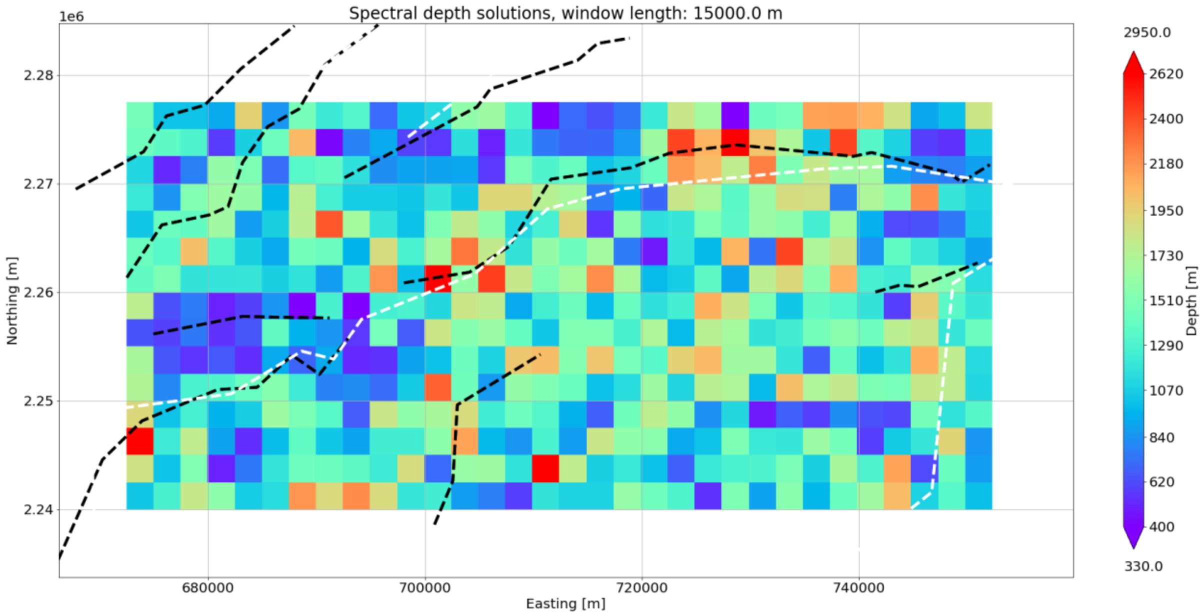

Fig. 21: Example of windowed depth calculations (data from Fig. 2)

The user may then click with the right mouse to finish the module and return to the main screen or click with the left mouse on any point. In the latter case, the two spectra (NS and EW directions) are plotted with the fitted lines (Fig. 22). The user is then asked to trace a new line to manually define a new depth or to make a simple click to accept, and this for both directions (i.e., to accept the automatic results and return to the map of solutions, two clicks are necessary).

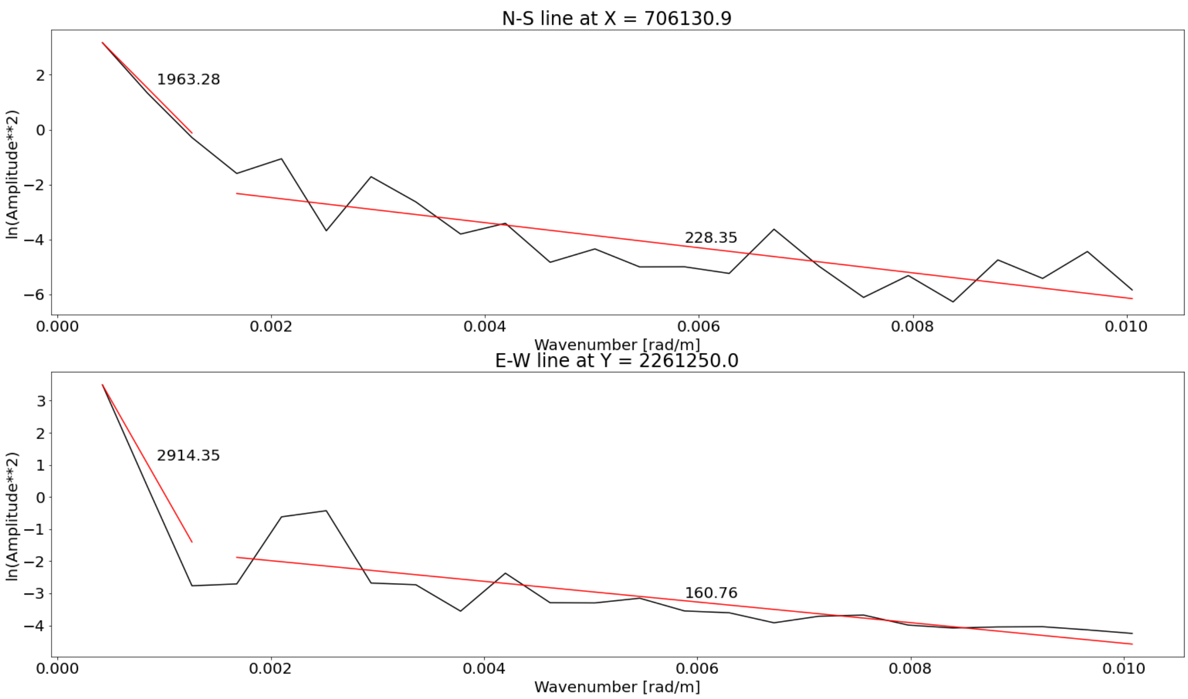

Fig. 22: Spectra of one point in NS and EW direction shown after clicking on a point of Fig. 21

History:

v.24.8.1: first beta version

Aug. 2024: An earlier version from 2023 was completely rewritten to be publishable on pypi.