MagB_inv: A high performance Matlab program for estimating the magnetic basement relief by inverting magnetic anomalies

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USER GUIDE

Description

MagB_inv uses an iterative procedure based on Parker (1972) Fourier domain forward expression of magnetic anomalies to determine the depth to the basement from gridded magnetic anomalies. The code is designed in Matlab environment (version R2013b) with an easy-to-use graphical interface (GUI) allowing the user an interactive control on managing the iterative procedure for a complete interpretation and illustrating the results data in interest without requiring any coding knowledge. The GUI also provides additional options to visualize the output data either in 2D maps and cross-sectional view. Outputs can be exported either numeric data or as images. Fig. 1 represents a flowchart of the present inversion.

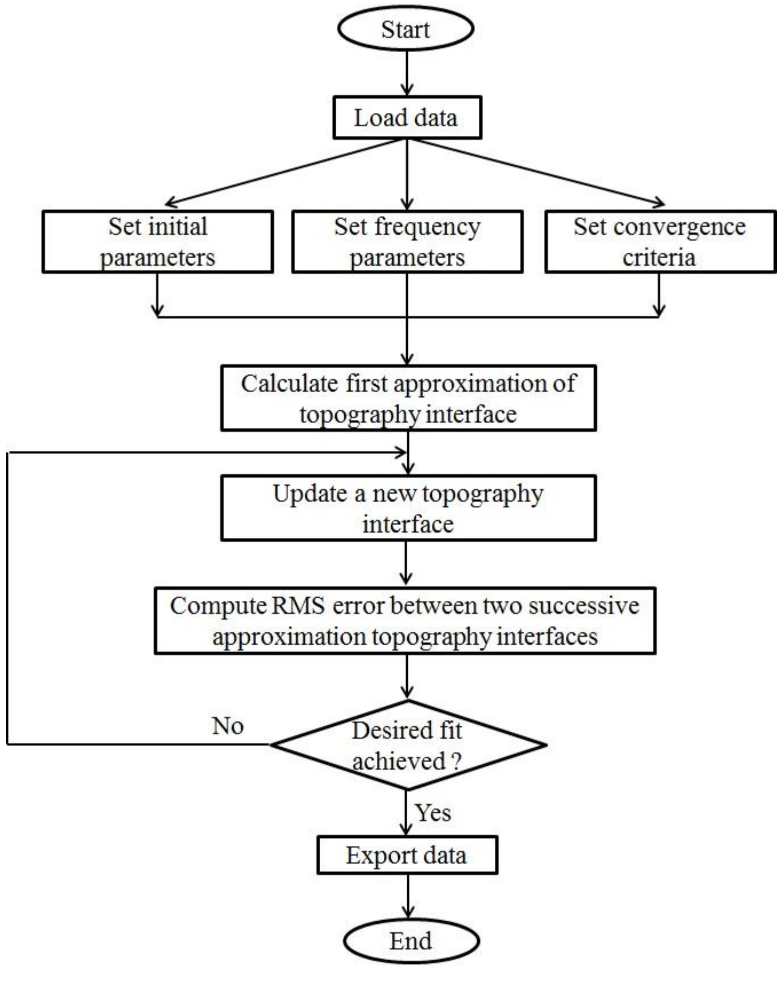


Fig. 1. Flowchart of MagB_inv code for magnetic basement estimation

- Parker, R.L., 1972. The rapid calculation of potential anomalies. Geophys. J. Roy. Astron. Soc. 31, 447–455.

Run the Code: Locate the program code to the working space of Matlab or vice versa the working space of Matlab to the source directory of the code and thereafter type the name of the code to the command window of Matlab.

By running of the MagB_inv program a simple graphical interface pops up covering the half of the screen to the left. The configuration of the main GUI window is illustrated in Fig. 2. Here the upper part of the window allows the user to track the mesh information of loaded data, as well as root of file. Below this window, an editable table enables the settings for the initial parameters, the filter parameters and the criterion for the termination of the iterative procedure (Fig. 2). The remaining part of the window is the display area for the input map.

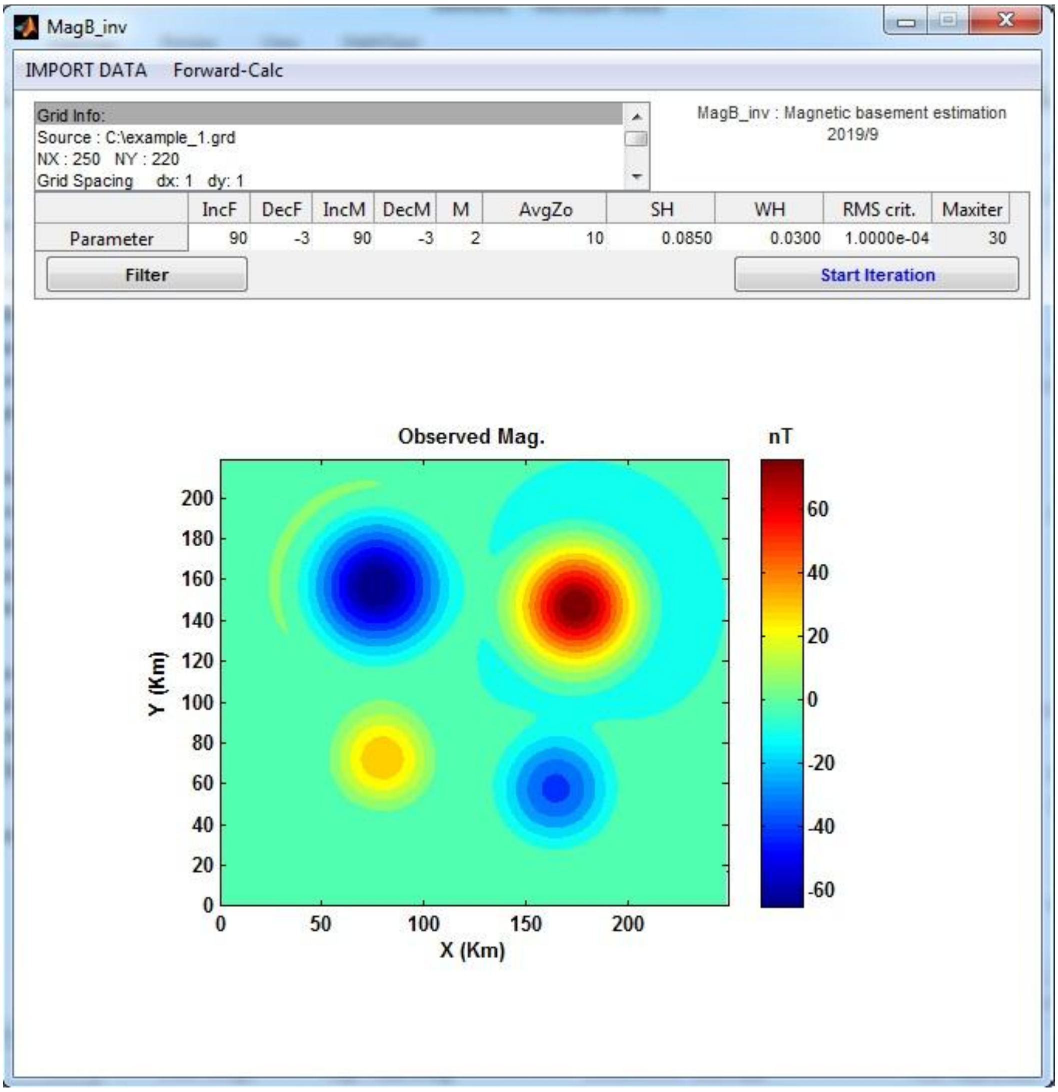


Fig. 2. Screenshot from MagB_inv main GUI after a successful data loading and performing the settings prior the start of the iteration procedure.

Required data and formats

Loading the magnetic data set is provided by the interactive "Import Data" menu located at the top left of the window which allows the user loading either a grid file compatible with

Golden Software Surfer formats (*.grd [Surfer 7 Binary grid / Surfer 6 text grid] or a three columns ascii-file containing gridded Easting/Northing/Field columns (*.dat, *.txt, *.csv). (Fig. 3).

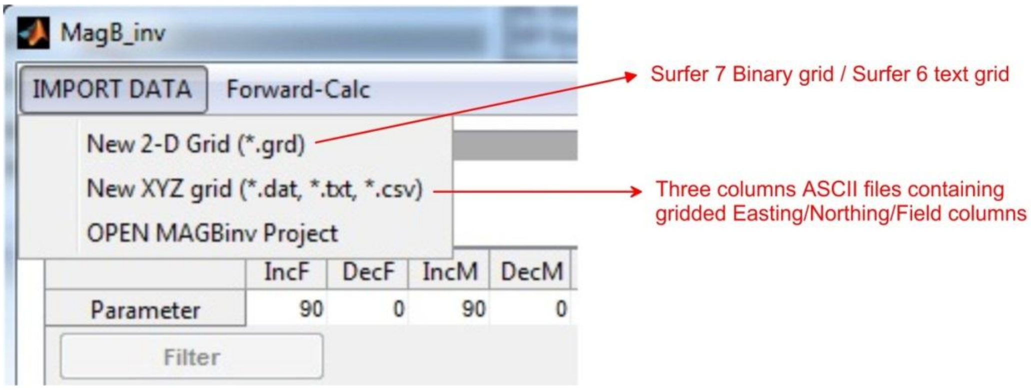


Fig. 3. Supported file formats for the gridded input magnetic data

The algorithm approves square as well as rectangular input grids. However, the grid interval is required to be equal along the east and north directions. Otherwise a warning box occurs in the case of incompatibility.

Inversion procedure and storing the outputs

After successful data loading, information about the active input grid is listed in the uppermost grid info box and a map view of the input is displayed. Then the required input parameters related to the ambient field and magnetization, the average depth of magnetic interface and the roll-off frequency parameters of filtering need to be entered in their related cells of the table component (Fig. 4). The units of the magnetic anomalies are nT, magnetization vector directions in degree, magnetization contrast in A/m and distances are in km. The behavior of the termination of the iteration procedure can be set by editing the criterion cell to zero for the divergence-mode or to a non-zero value (default 10^{-4}) for the convergence-mode. The iterative procedure in the divergence-mode terminates when the root mean square error (RMS) between the two estimated data sets from successive steps of the iteration has increased relative to the previous step whereas in the convergence-mode the iteration stops when the RMS is below a predefined threshold value. In all cases, however, the iterative procedure stops when the user-defined maximum number of iterations has been accomplished.

Desription of abbreviations in the control panel are as below:

IncF/IncM: inclination angle of ambient field and magnetization, respectively.

DecF/DecM: declination angle of ambient field and magnetization, respectively.

Z0: average depth of the interface.

RMS crit.: Iteration stop criteria. (if Rms crit. = 0, then divergence mode is used for termination; if Rms crit. > 0 then the convergence mode is used for termination).

Maxiter: The maximum number of iteration in the case of none of the stopping criteria has been accomplished.

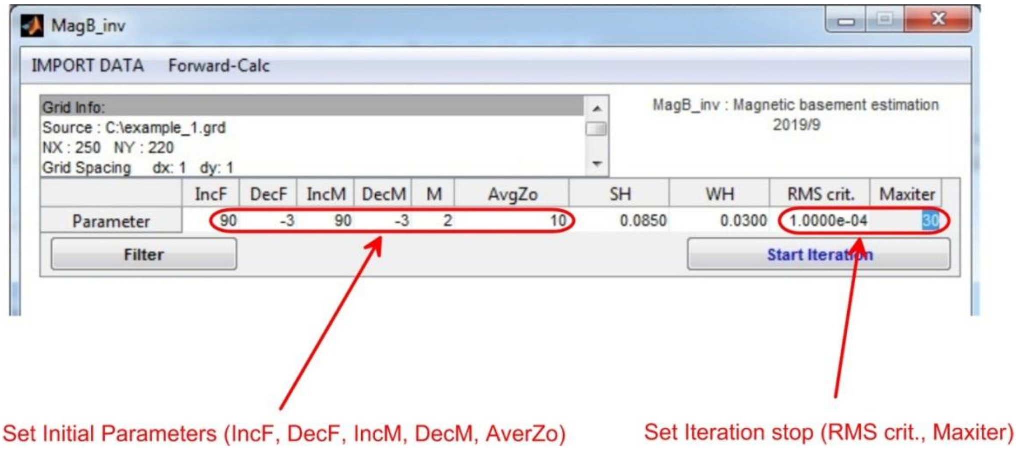


Fig. 4. Input parameters related to the ambient field, magnetization and the average depth of magnetic interface and settings of behaviour of the termination of the iterative procedure.

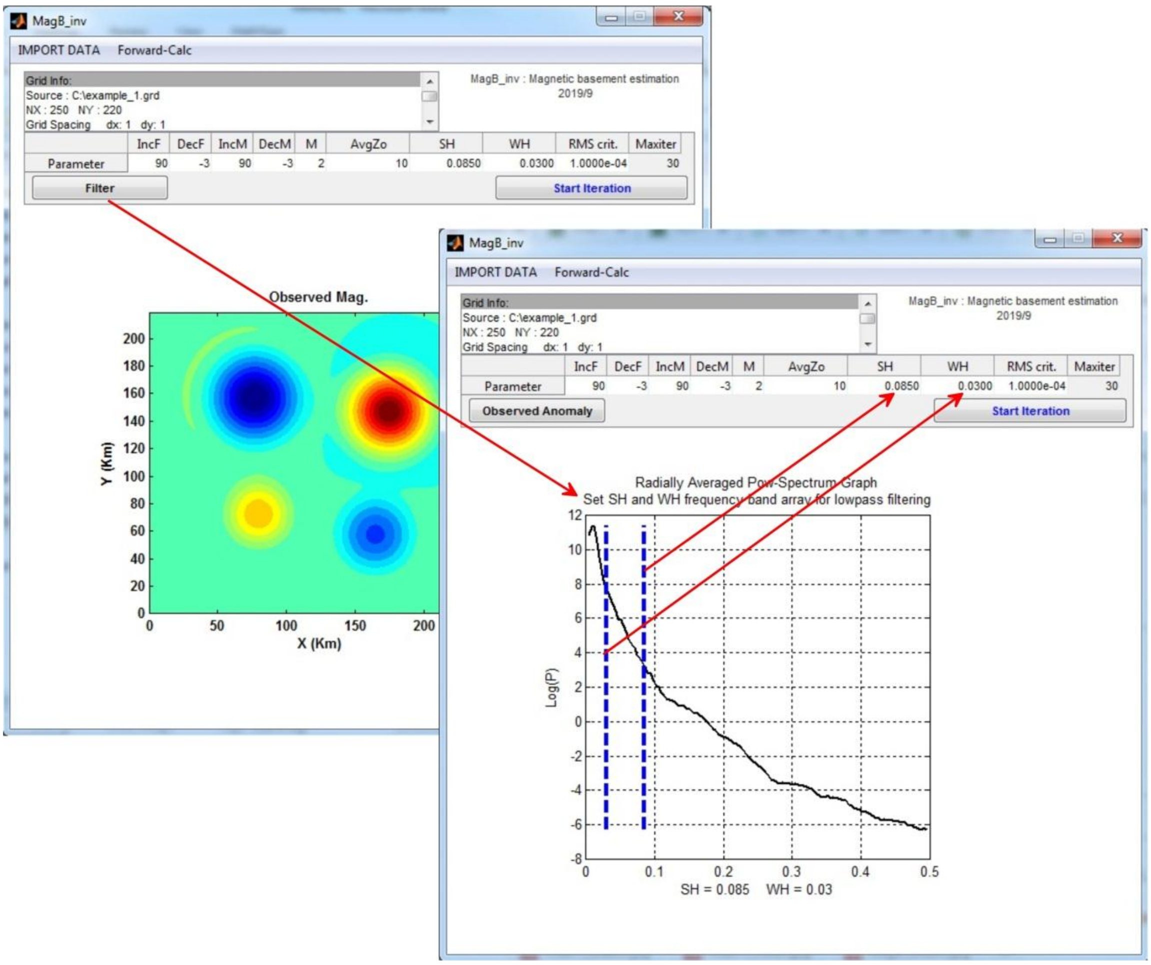


Fig. 5. Setting the roll-off frequency parameters of the high-cut filter.

The "Filter" menu item located below the settings enables the user configuring the roll-off frequencies SH and WH also interactively by mouse clicks on the radially averaged power spectrum plot of the data (Fig. 5). The choose of a proper SH/WH can be attained by analyzing the power spectrum content of the data. A plot of the logarithm power spectrum versus wavenumber usually shows several straight-line segments that decrease in slope with increasing wavenumber. Generally, low radial wavenumbers mainly relate to deep sources, and intermediate radial wavenumbers mostly correspond to shallow ones, while high radial wavenumbers are dominated by noise. Hereby, the convergence of the series during the iterative procedure can be secured by standing of SH and WH filter parameters to the frequency limit of the linear segment associated with the mean depth to isolate.

After confirming the inputs, the algorithm is iteratively continued until the behavior of the termination is realized. Finally, the code appends the "inverted basement depth and the magnetic response due to this depth model, the difference between the observed and calculated magnetic anomalies and the RMS errors after each iteration to the temporary *.mat file created in relation with the observed input grid". Eventually, the code pops up a new control window next to the main GUI that allows the user to visualize any of the output maps/graphics which can be preferred interactively with simple mouse controls (Fig. 6). By preference, the results at any section of the maps can also be illustrated together with their profile views (Fig. 7). Color adjustment on maps or a 3D view are additional tools provided by this control window.

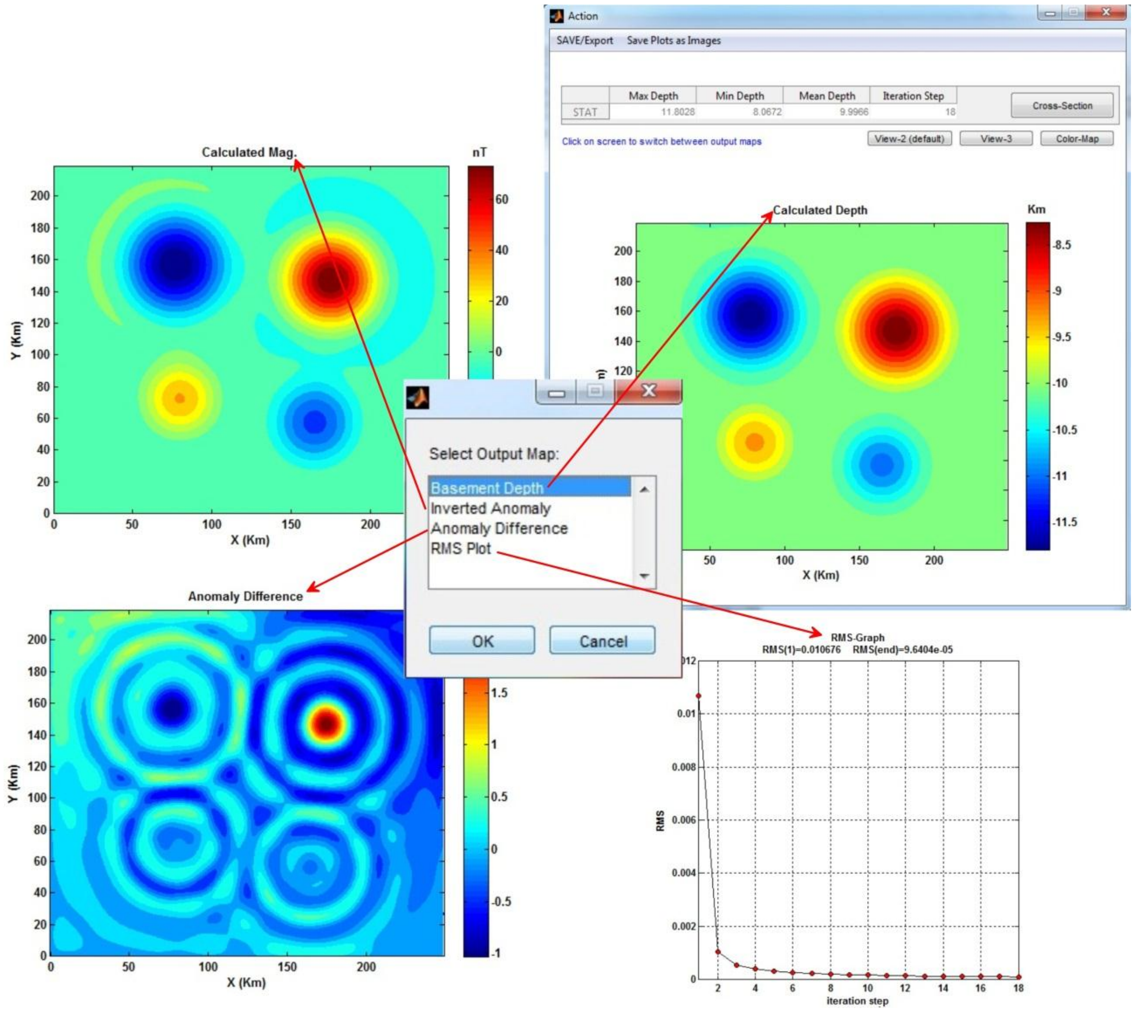


Fig. 6. The output GUI window after the iterative process. Selection of output maps/graphics is enabled by a popup window activated by mouse a click on screen.

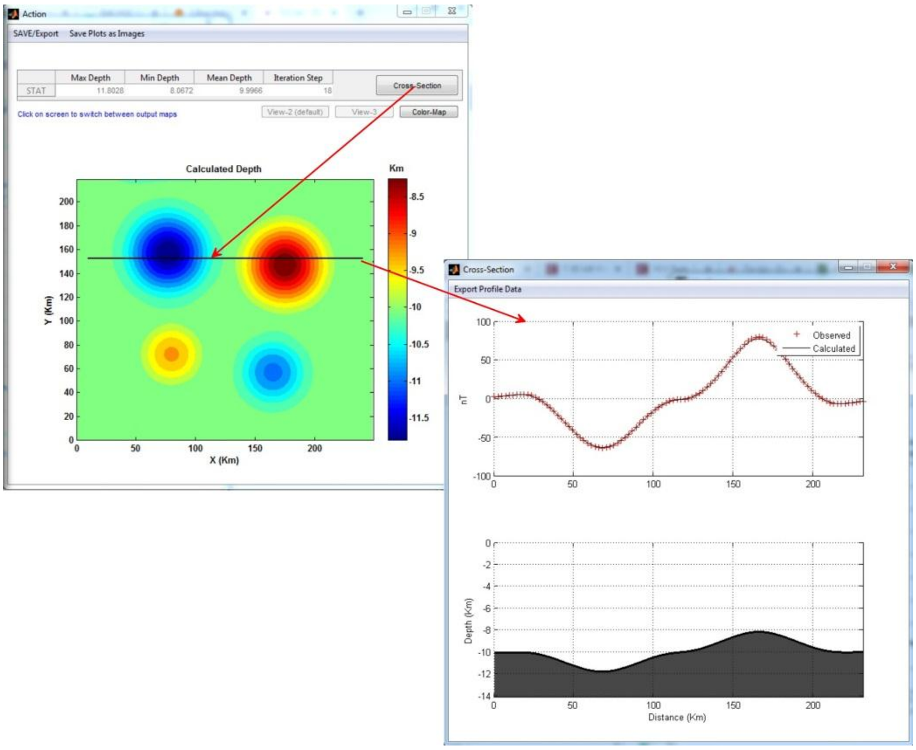


Fig. 7. Cross-section view style from user defined profile position enabled by "Cross-Section" menu button.

All of the output data can be exported by a user defined name either to a *.mat file comprising the complete inputs/outputs or to separated files of *.grd format for the maps and *.dat format for the RMS vector and for any extracted profile data (Fig. 8). Exported *.mat files from MagB_inv code can be reloaded by the "Import Data" menu at the main GUI of the program. Thus, saving by this format has the advantage to re-view all the inputs, settings and the interpretation results at any time. Additionally, all the input/output maps and graphics illustrated at the GUI windows of the code can be exported as portable network graphic (*.png) images of 500 dpi in resolution.

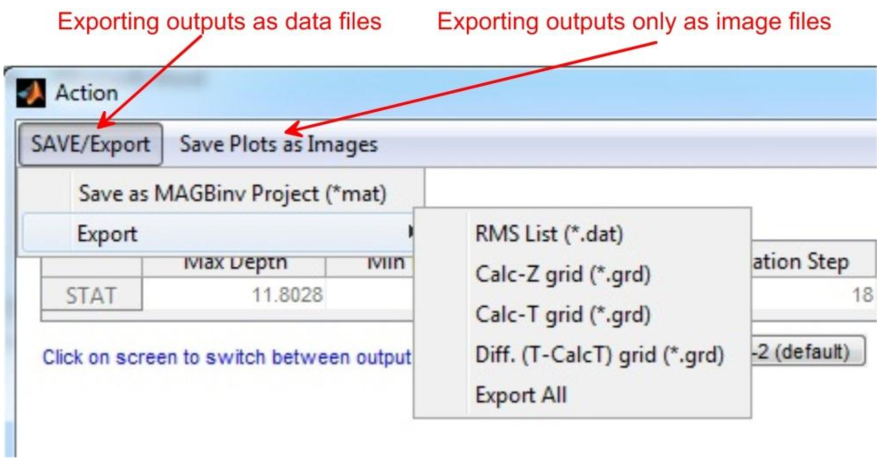


Fig. 8. Export menu items at the output GUI window.

Description for variables in a *.mat file exported from MagB_inv code: Data and their variables in Matlab binary file can be retrieved into the storage simply by writing "load (‘filename*.mat’)” to the command window or to a script in Matlab. Variables from an MagB_inv *.mat file storage are as follows;

T: matrix of input magnetic anomaly grid,

nx, ny: number of columns and rows of the input grid, respectively.

dx, dy: grid spacing distance in x and y direction.

xmin, xmax, ymin, ymax: map limits in x and y direction.

x, y : mesh of of grid node coordinates in x and y direction.

SH, WH: roll-off frequencies used for high-cut filter during the iterative process.

Zcalc, Tcalc, Tdiff: calculated basement grid, calculated magnetic response grid and the difference between the input and output magnetic anomalies, respectively.

rmstor: rms values stored during the iterative process.

filnam: source file name of the input data grid.

setto: vector containing the settings of ambient field and magnetization, the mean depth, the criterion of the iteration stopping and the maximum iteration number in order of

IncF	DecF	IncM	DecM	M	Z0	RMS crit.	Maxiter

Note: an exported *.mat files from MGB_inv code can be reloaded by the “Import Data” menu at the main Gui of the program to review any previous interpretation.

<u>Additional function for forward modelling</u>

Besides the inversion scheme, the code also includes an in-built GUI window for performing forward calculation to obtain magnetic model anomalies from an input of depth grid. The related GUI window for such a process can be activated by the button press on “Forward-Calc” menu item located at the uppermost of the main GUI (Fig. 9). Loading the depth data set is provided by the interactive “Load Depth Grid” menu located at the top left of the window which allows the user loading a grid file compatible with Golden Software Surfer formats (*.grd [Surfer 7 Binary grid / Surfer 6 text grid]). After successful data loading, the required input parameters related to the ambient field, magnetization and the average depth of the interface need to be entered in their related edit boxes which appears by the menu item of the “Settings & Calc” button (Fig. 9). After confirmation, the code performs the forward calculation of magnetic anomalies and maps the result. The user can export the resulted map either as a data file (*.grd) or as an image file (*.png).

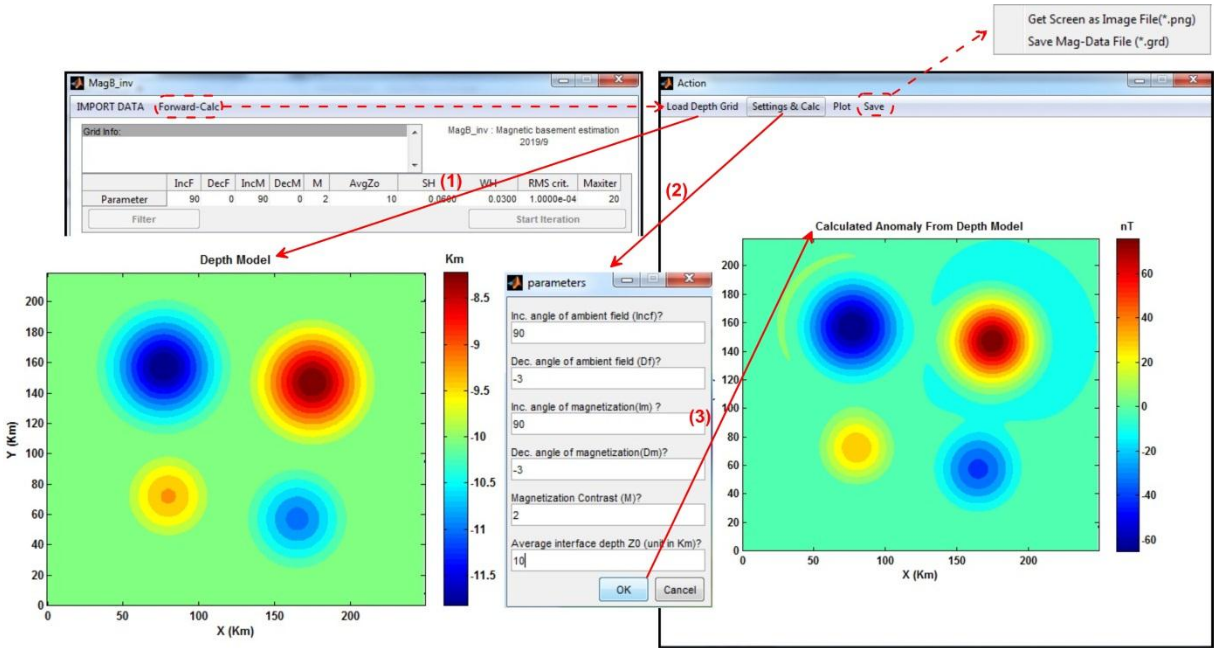


Fig. 9. Steps for forward calculation to obtain magnetic model anomalies from an input of depth grid.

FUNCTIONS in MagBase_inv Code:

<u>Data loading functions</u>

impgrd: imports a new 2-D grid, memorizes to temporary file, updates inputs table content.

> **grd2loader:** Checks format of 2-D grid input, searches for format errors
>
> **lodgrd6txt:** reads text grid format (*.grd)
>
> **lodgrd7bin:** reads binary grid format (*.grd)

impgrdat: imports new XYZ column data, memorizes to temporary file, updates inputs table content.

> **lodgrdatfile_Callback:** reads XYZ ascci format file (*.dat,*.txt,*.csv), searches for format errors

impordep: imports a new 2-D depth model grid for forward calcultion procedure, memorizes to temporary file

<u>Inversion/forward modeling functions</u>

> **startiter:** retrievs inputs from table content, starts inversion procedure, memorizes outputs (basement, calculated magnetic anomaly, anomaly difference, rms variation)
>
> > **get_parameters:** reads inputs table content, initialize parameters.
>
> **maininv:** performs the inversion procedure
>
> **calcmag:** retrievs inputs, initialize parameters, calls **forwardmag** function, memorize forward model

Calculator functions

dircosin: calculates unit vectors of the magnetization and the ambient field.

paddData: zero padding of gridded data

getfreqs: calculates wavenumbers k, kx,ky

filt_d: calculates 2-D filter cofficients (low-pass)

forwardmag: performs forward calculation of magnetic anomalies from gridded depth model

raps_data: calculates radially averaged spectrum

Display functions

mapper: displays a color filled contour map of gridded data (color map is jet in default)

colormapeditor: starts colormap editor ui (in-built function in matlab).

rmsplot: displays the rms variation obtained during the iteration steps.

map3v: displays 3D contour map of basement depth.

errormess: displays an error message window explaining the kind of error.

rapsplot: plots the radially averaged spectrum of input data and two vertical lines (in blue) indicating the current roll-off frequencies of the filter design (SH and Wh).

setlin: enables the user to set the frequency band array (SW-WH) interactively by mouse control

get_SHWH: updates the cells related to SH and WH in inputs table according the interactive selection of these parameters on raps plot

tbl_selectshwh: updates the positions of the vertical lines related to the roll-off frequencies SH and Wh in raps plot according the manual input in inputs table

getcross: creates a new GUI for cross-sectional view, interpolates data (observed anomaly, calculated anomaly and basement) between interactively selected two coordinates

plotcross: plots cross-section data of observed and calculated anomalies and basement relief

instat: instant display of the maximum/minimum/mean depth and the current step of iteration during the on-going iterative procedure (in the table in outputs GUI)

list1w: wites the mesh information of loaded data, as well as root of file to the listbox located at the left upper part of the main GUI window.

switcmp: toggle between contour maps of imported depth model and the calculated magnetic anomaly

selectoutmap: displays a dialog box for selecting the desired output to plot.

selectoutmapimag: displays a dialog box for selecting the desired output to save as an image (screen shot).

plotcontrol: checks and directs to the plot style that user has selected (2D, 3D, cross-section).

GUI related functions

createMainwindow: creates main GUI

createwindow2: creates an empty figure next to main GUI

createmenu2: creates menu items related to inversion procedure

createFWgui: creates menu items related to forward-calc procedure

closewindows: closes all windows opened (except the main GUI)

openproj: Re-loads a complete interpretation saved as a project file (matlab binary file).

expofig: creates a GUI for taking screen shots of desired plots.

return2menu2: closes GUI created by **expofig** and returns to GUI created by **createmenu2**.

posfig1: resets the position of main GUI to default.

Saving functions

savbut: enables the user to select the data to be exported**.**

savmat: exports all inputs/outputs as a single matlab binary file (*.mat)

savout: exports the desired output as data file. Maps are stored as 2D data in *.grd format where as the RMS variation is stored in ascii format (*.dat).

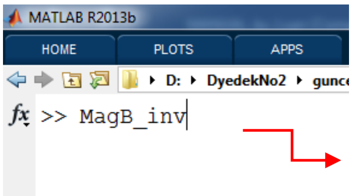
ploprint: exports plot on screen as *png image format with 500 dpi in resolution

savcross: exports cross-section data to an ascii file (*.dat)

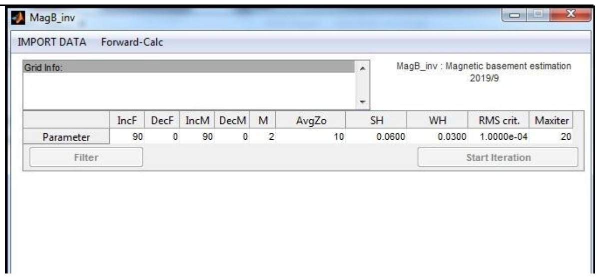
saveforward: exports the calculated magnetic anomaly grid due to the depth model.

grdout: saves output as grid format (*.grd)

Example-1. Forward modelling

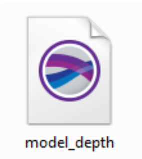
<table>
<tr><th>Steps</th><th>Part of Screen</th></tr>
<tr><td>1- run MagB_inv</td><td>


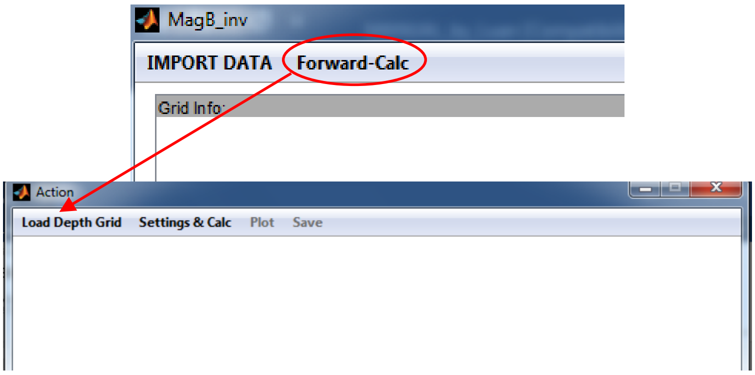
Matlab command window

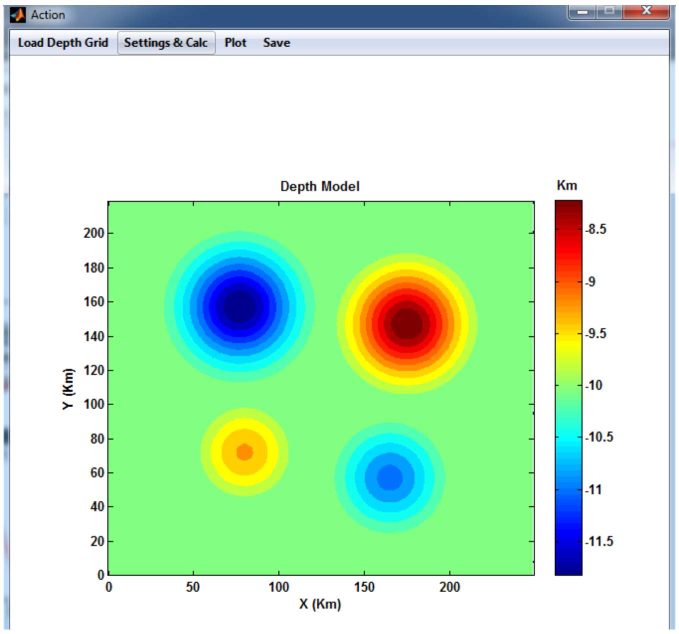


</td></tr>
<tr><td>2- Activate forward GUI window by Forward-Calc Menu

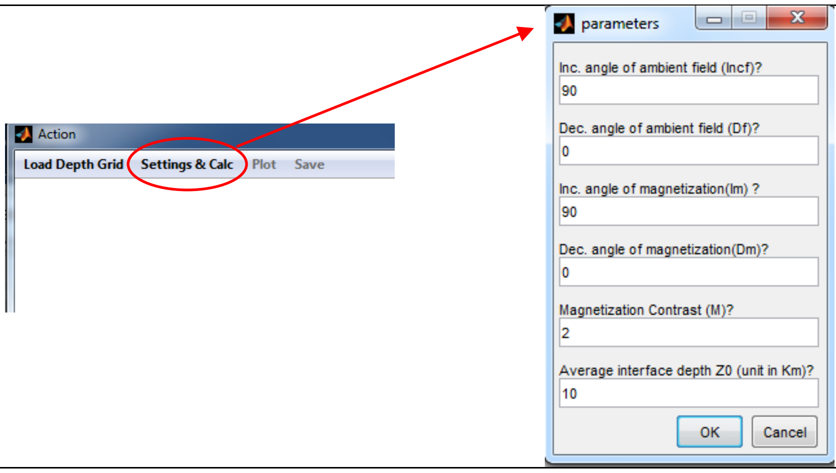
3- Load “model_depth.grd” input file by “Load Depth Grid” menu



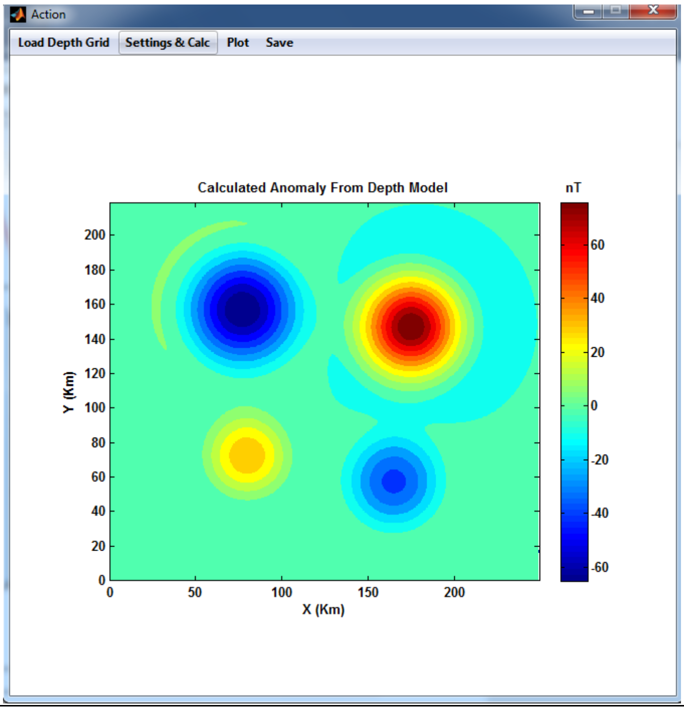
</td><td>


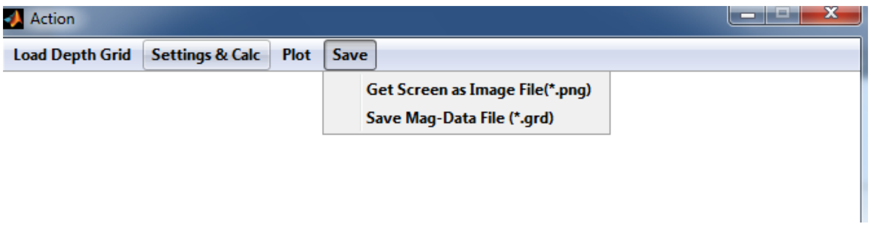


</td></tr>
</table>

<table>
<tr>
<td>4- Input parameters related to the ambient field and magnetization, the average depth of magnetic interface by “Settings & Calc” menu</td>
<td>


</td>
</tr>
<tr>
<td>5- Confirm inputs and start forward calculation of magnetic anomalies.

(Use “Plot” menu to toggle between input/output maps)</td>
<td>


</td>
</tr>
<tr>
<td>6- Export result by “Save” menu item.</td>
<td>


</td>
</tr>
</table>

Example-2. Inversion modelling

<table>
<tr><th>Steps</th><th>Part of Screen</th></tr>
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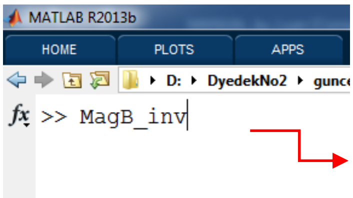
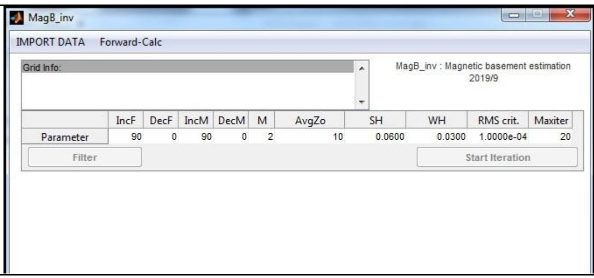
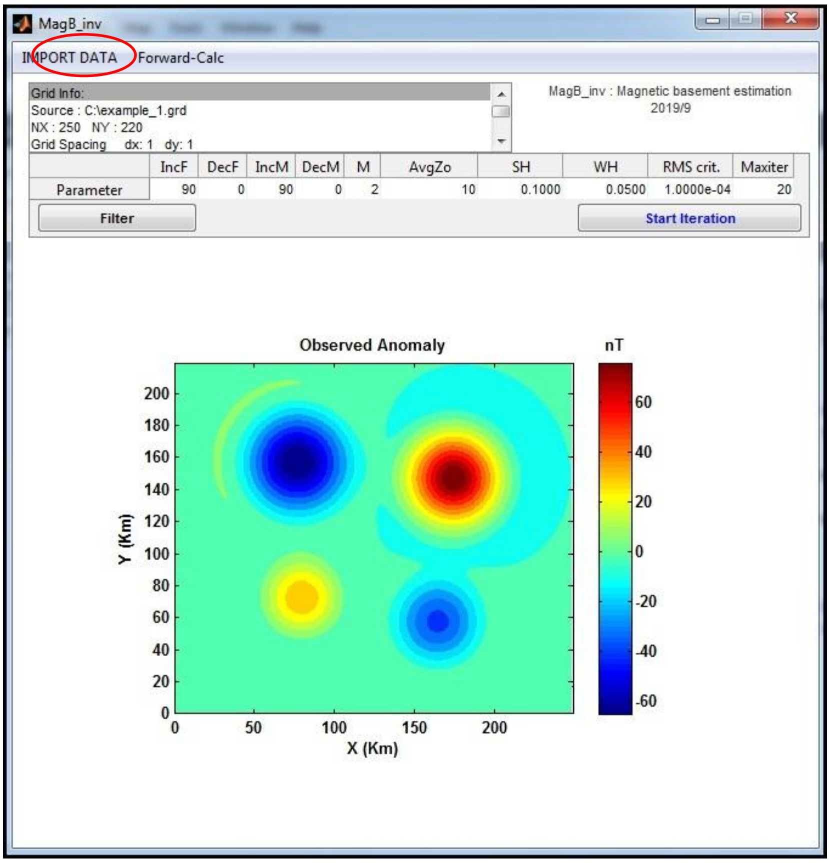
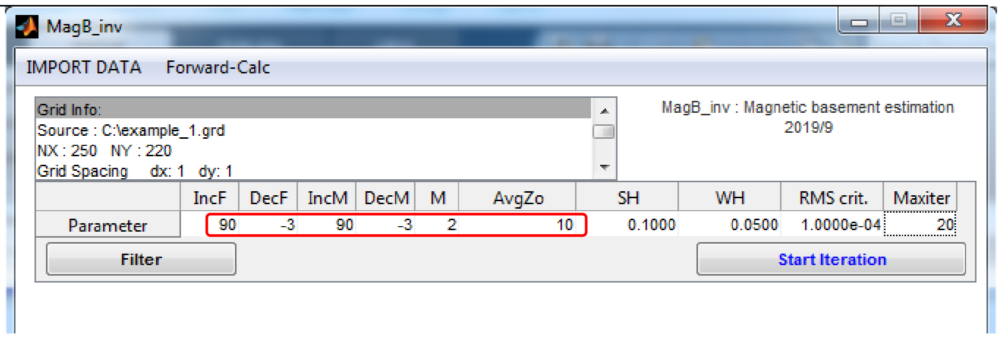


Matlab command window

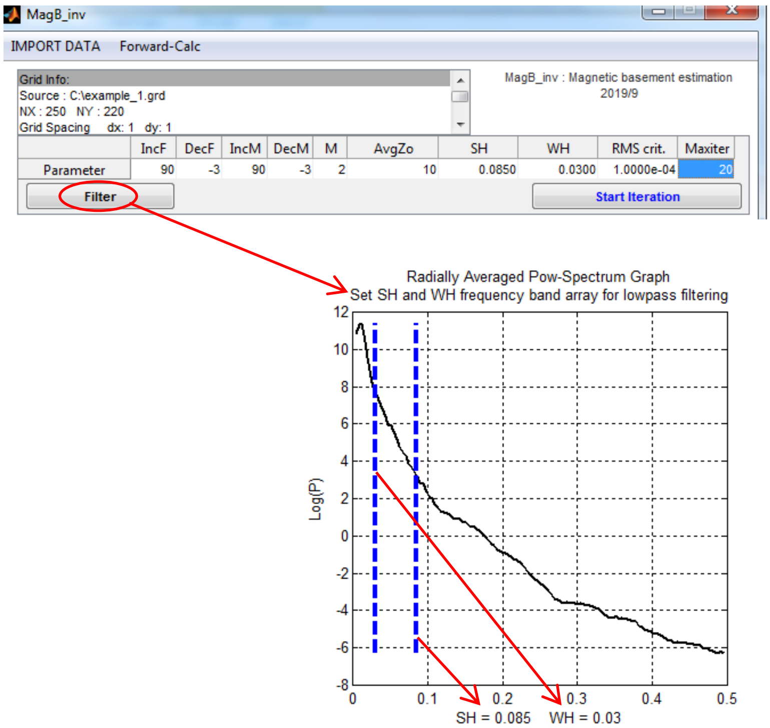


</td></tr>
<tr><td>2- Load “example_1.grd” input file by “IMPORT DATA” menu</td><td>


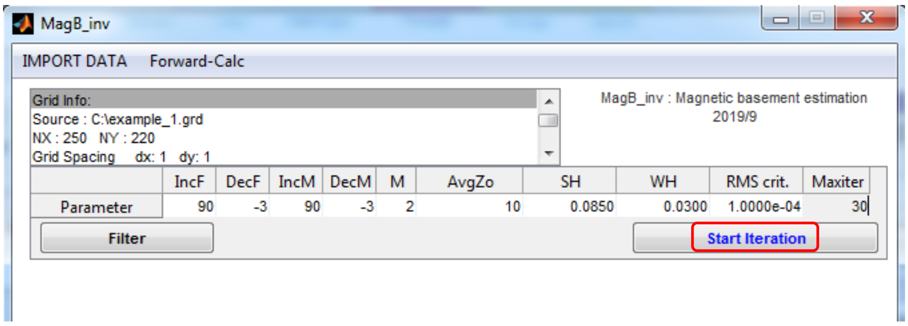
</td></tr>
<tr><td>3- Input parameters related to the ambient field and magnetization, the average depth of magnetic interface</td><td>


</td></tr>
</table>

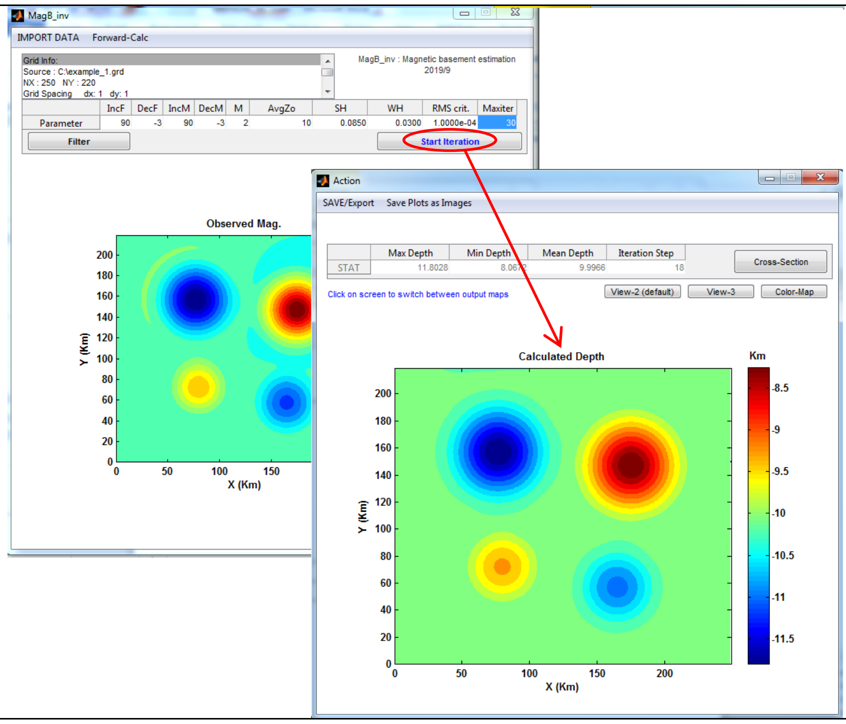
4- Set the roll-off frequency parameters of the high-cut filter by the “Filter” menu



5- Set iteration stop (RMS crit., Maxiter)



6- Confirm inputs and start depth calculation of magnetic interface by “Start Iteration” menu



7- Export outputs as data files and image files by “SAVE/Export” and “Save Plots as Images” menu items