# SAMOVAR 6x7

## USER'S GUIDE

written by

Anatoly Legchenko

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# Contents

# Introduction

Magnetic Resonance Sounding (MRS) is distinguished from other geophysical tools used for groundwater investigation because of measurements of the magnetic resonance signal generated by groundwater molecules. A pulse of alternating current energizes a wire loop set up on the ground surface and the MRS signal allows detecting groundwater with a high degree of reliability. Measurements with varied pulse magnitudes then reveal the depth and thickness of water-saturated layers. The hydraulic conductivity of aquifers can also be estimated using boreholes for calibration. MRS can be used for both predicting the yield of water supply wells, and for interpolation between boreholes, thereby reducing the number of holes required for hydrogeological modeling.

SAMOVAR is a software for the MRS 1-D forward modeling and inversion (inverse modeling). SAMOVAR is fully compatible with data issued from NUMIS, NUMIS$^{PLUS}$, NUMIS$^{POLY}$, NUMIS$^{AUTO}$ and NUMIS$^{LITE}$ instruments fabricated by IRIS Instruments.

The following programs compose the SAMOVAR 6x7 software package:

- SAMOVAR 6x7: computing - MRS linear filter (file: Samovar_6x7_comput.exe).
- SAMOVAR 6x7 modeling - 1-D forward modeling of MRS signals (Samovar_6x7_mod.exe).
- SAMOVAR 6x7 inversion - data processing and 1-D inversion of MRS data (Samovar_6x7_inv.exe).
- SAMOVAR – HYDRUS convertor - inter-software data convertor (Samovar_12x1a_HYDRUS_conv.exe).

**System requirements**

SAMOVAR 6x7 has been developed for Windows 32-bit environment. It works with the Windows NT, XP and later versions, including Windows 10.

All the functionalities are guaranteed for the following PC configuration (the *minimum requirements*):

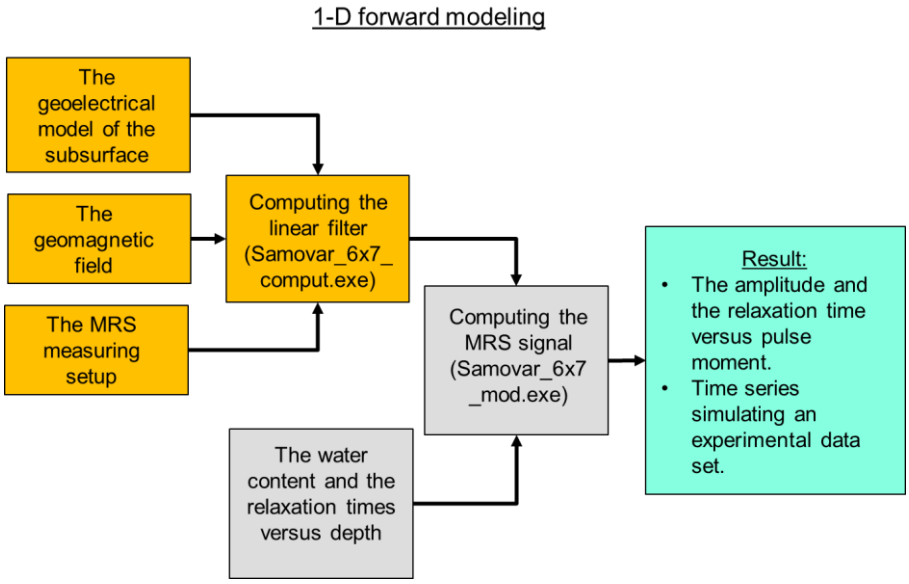
- Windows NT, XP and later
- Pentium III microprocessor (800 MHz) and better
- 128 Mb RAM memory and more
- 1024 x 768 screen resolution and better

## Installing SAMOVAR 6x7

For installing Samovar 6x7 you need to unzip the compressed file “Samovar_6x7.zip” and copy all the files to a folder in which you may to read and write. For example: “C:\D\work\tst-book\Samovar_6x7”.

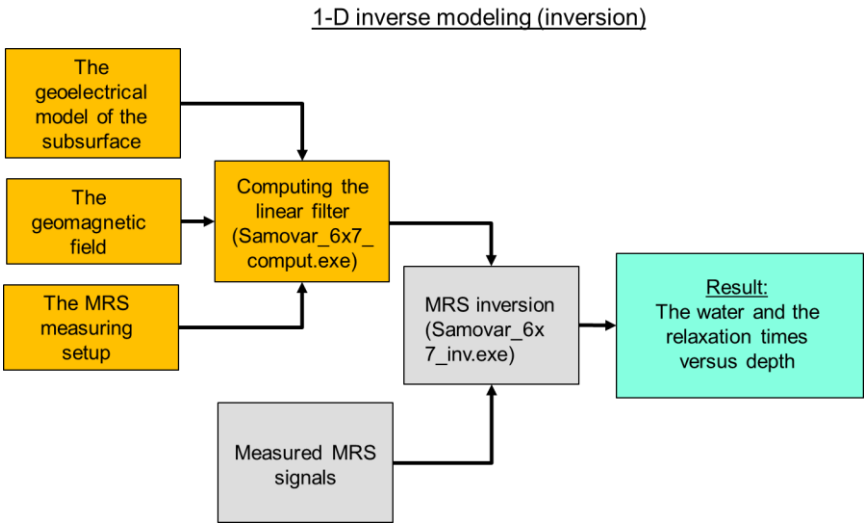
## 1-D forward modeling workflow

The forward modeling procedure allows computing MRS signals corresponding to the prescribed measuring conditions with a vertical profile of the water content. The measuring conditions comprise: the electrical resistivity of the subsurface; the magnitude and the inclination of the geomagnetic field; the MRS measuring setup. The MRS signals are computed in two steps: 1) the linear filter contains the parameters of the subsurface and of the measuring setup; 2) the water content and the relaxation times are added to the subsurface described by the linear filter. The output of the MRS forward modeling is a data set simulating experimental data measured with the NUMIS MRS instrument.




## 1-D inverse modeling (inversion) workflow

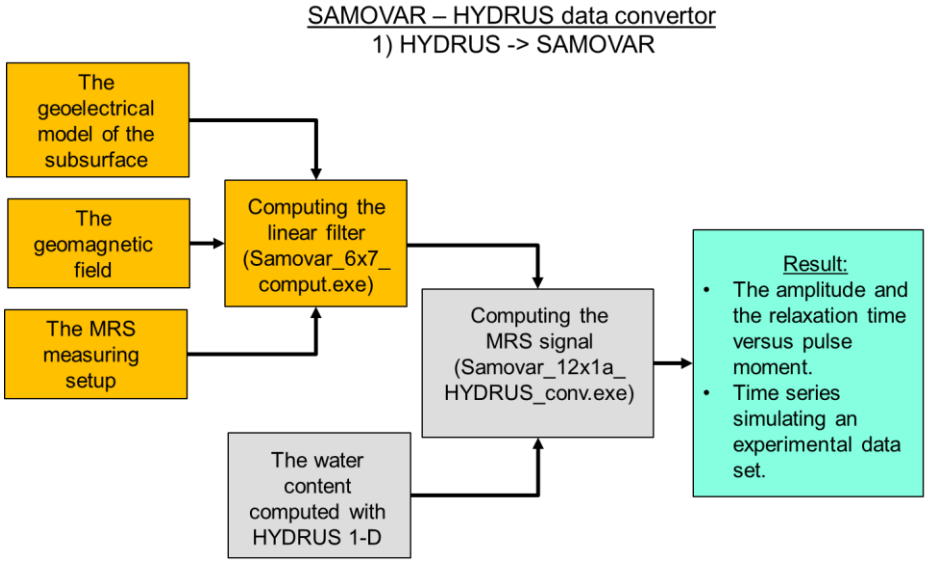
The inverse modeling (inversion) procedure allows computing the water content and the relaxation time vertical profiles, considering the prescribed measuring conditions and corresponding to measured or simulated MRS signals. The measuring conditions comprise: the electrical resistivity of the subsurface; the magnitude and the inclination of the geomagnetic field; the MRS measuring setup. The MRS inversion routine allows fitting measured signals by synthetic signals computed using an inverse model. The output of the MRS inverse modeling is the inverse model that fits experimental data and composed of the vertical profiles of the water content and the relaxation times.




## SAMOVAR – HYDRUS convertor

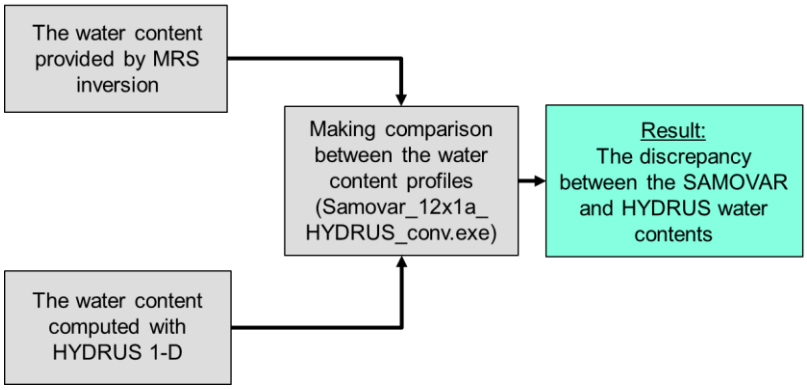
The SAMOVAR – HYDRUS data convertor allows two principal tasks.

1) The MRS forward modeling can be carried out using the water content in the subsurface provided by a water flow modeling with the HYDRUS-1D software. The output of the MRS forward modeling is a data set simulating experimental data measured with the NUMIS MRS instrument.




2) The water content in the subsurface provided by MRS inversion can be compared with that provided by a water flow modeling carried out with the HYDRUS-1D software. The discrepancy between these two data sets may allow revising the water flow model and/or the MRS inverse model. The joint inversion of the SAMOVAR and HYDRUS-1D data is not included in the SAMOVAR 6x7 software package.

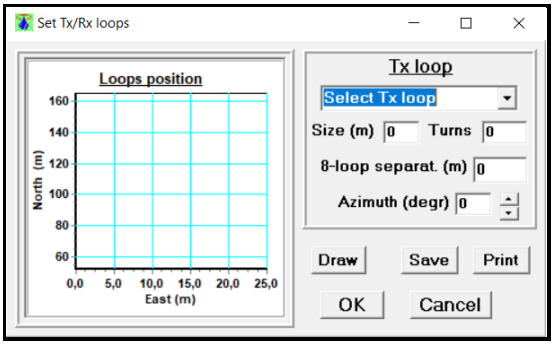
SAMOVAR – HYDRUS data convertor
2) SAMOVAR ->HYDRUS



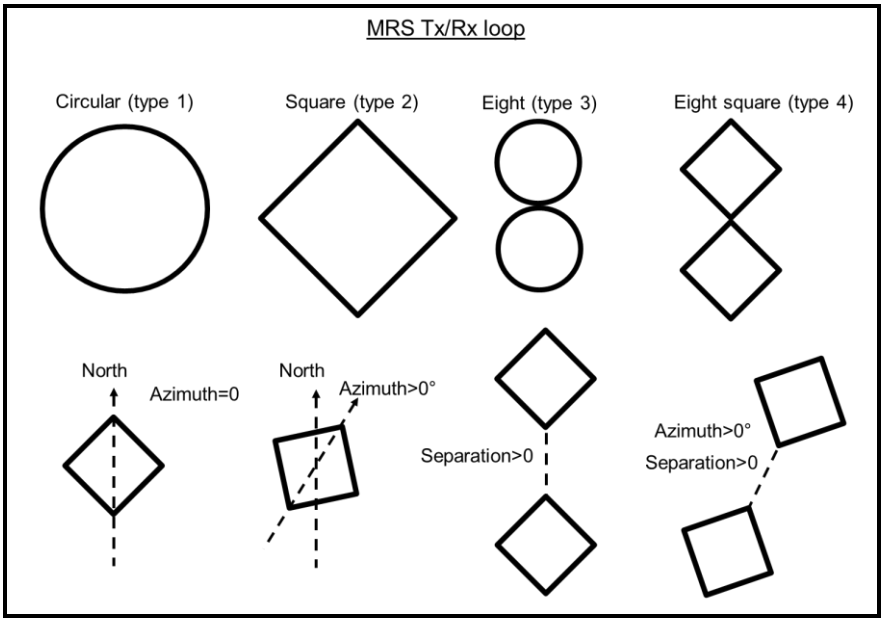
# Chapter 1. SAMOVAR 6x7: computing the linear filter

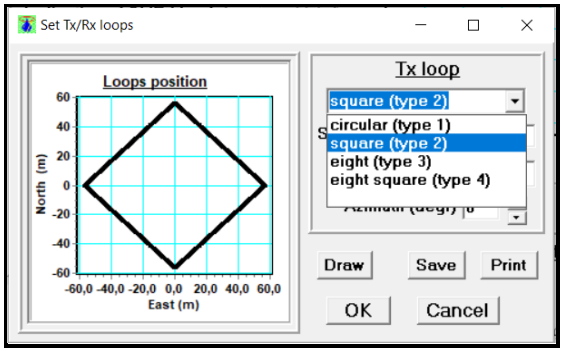
## Setting Tx/Rx loop

The first step comprises selecting the measuring loop.

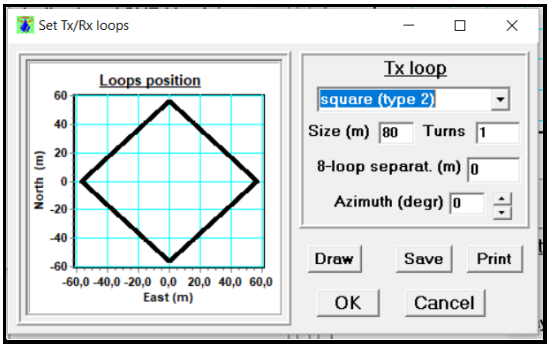



Loop types supported by SAMOVAR 6x7:



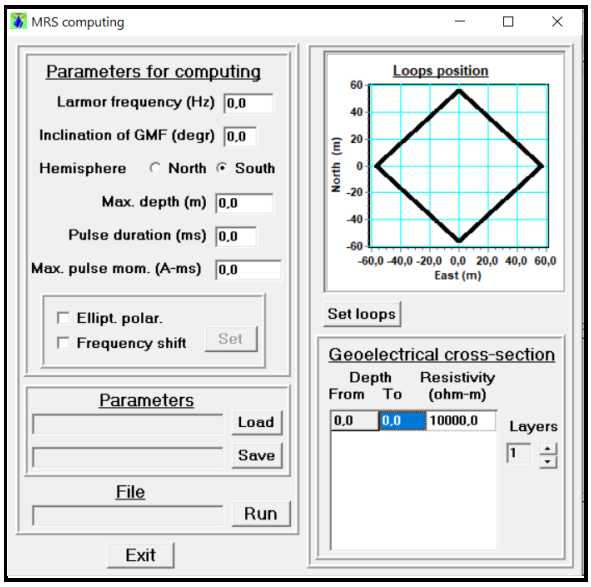



Setting the loop geometry.




The loop geometry can be visualized (***Draw***) saved as an image (***Save***) or printed out (***Print***). ***OK*** button confirms the loop.

## Setting computing configuration

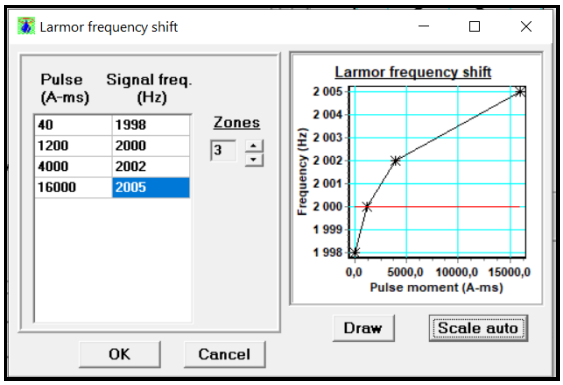



The configuration window comprises four major sections.

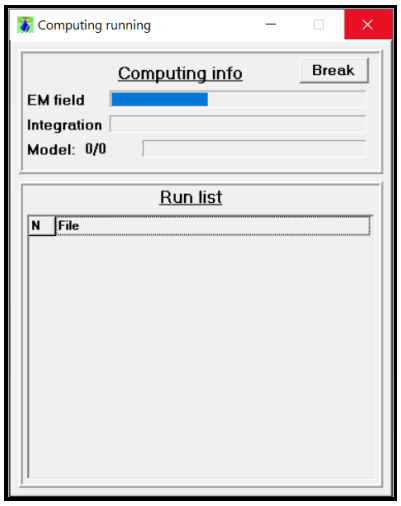
***Parameters for computing*** menu allow setting the information about the geomagnetic field (GMF): the Larmor frequency $f_0$ is proportional to the magnitude of the GMF $B_0$ ($\omega_0 = 2\pi f_0 = \gamma_p B_0$); the GMF inclination, including the hemisphere of a measuring site; the max depth of the linear filter computing (the recommended value is equal to 1.5 of the loop size); the max value of the pulse moment (the recommended value is 16000 A-ms) and pulse duration (the recommended value is 40 ms); by selecting the elliptical polarization one will use it instead of the linear one (select); the frequency shift between the measured signal frequency and the pulse frequency (both values are provided by the measuring device).
***Loop position*** graph shows the loop geometry (***Set loops***).
***Geoelectrical cross-section*** table allows setting the number and geometry of the electrically conductive layers in the subsurface.

***Parameters*** menu allows saving and loading computing configurations for the multiple use. ***File*** section starts computing of the linear filter (Run).

***Frequency shift*** table contains the frequency of measured signal versus pulse moment. The right-hand graph shows the signal frequency variation (black line) and the pulse frequency (red line) plotted versus pulse moment. The graph can be scaled using the mouse buttons.

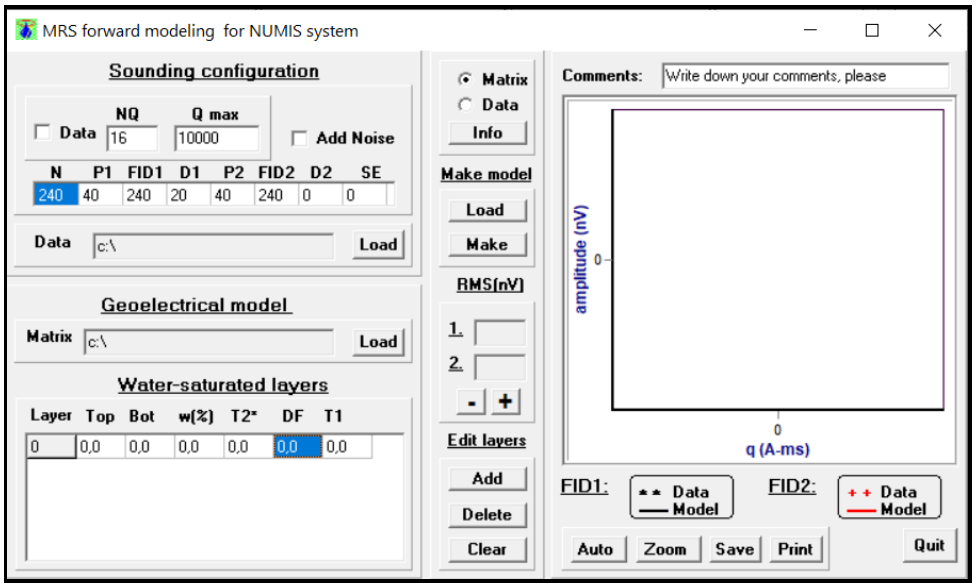



***Computing running*** window shows computing progress, which can be canceled (***Break***) before finishing. The ***Run list*** menu is not activated for the SAMOVAR 6x7 version.



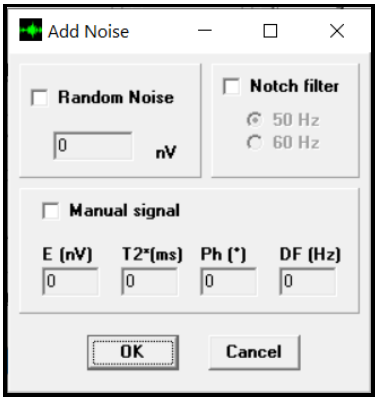

Computing results are stored in a file "*name.mrm*" (160 kB) and the computing configuration in a file "*name.nmc*" (1 kB). It is recommended to check the file sizes before using the linear filter. Incorrect computing may cause problems for the forward modeling and inversion.

# Chapter 2. SAMOVAR 6x7: forward modeling




***Sounding configuration*** menu allows setting:

- The number of pulses and the max value of the pulse moment.
- The measuring sequence in ms (N – noise record, P1 – the first pulse, FID1 – the signal record, D1 – the first delay, P2 – the second pulse, FID2 – the signal record, D2 – the second delay, SE - the signal record).
- These parameters can be set equal to the data set parameters (***Load***). The data set file "*name.nov*" is generated by the inversion routine. Raw data cannot be loaded.
- A random noise can be added to the synthetic time series (***Add Noise***):



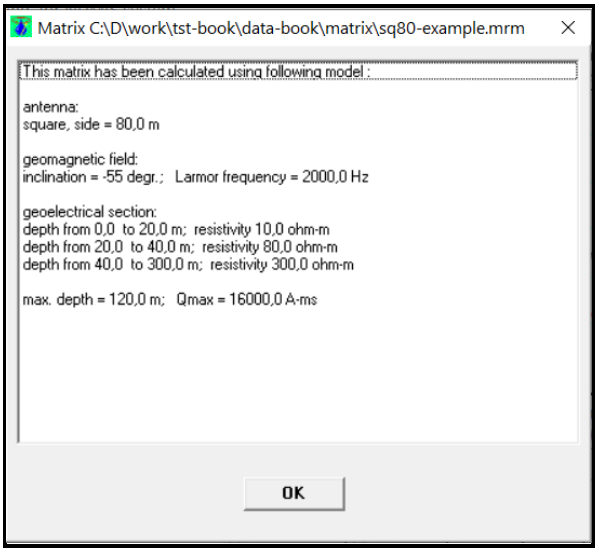

For testing the data processing, the synthetic records can be filtered with a notch filter and a manual signal with known parameters can be used.

***Geoelectrical model*** is provided by the linear filter also notated as "the matrix" (***Load***).

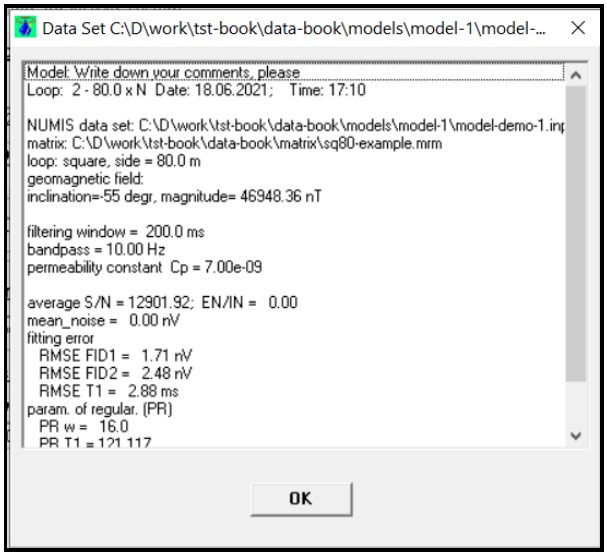
***Water-saturated-layers*** table allows setting the top and the bottom of water-saturated layer with the water content (in %), the relaxation time and the frequency shift for each layer. The table can be edited using "***Edit layers***" buttons. For computing MRS response corresponding to the table, just double-click selectin one of the table cells. Each signal parameter can be increased

or decreased by using "**+**" or "**-**" buttons of the ***RMS(nV)*** section. The root-mean-square error between the synthetic and the measured signals will be automatically computed if a data set is loaded. This option allows fitting the experimental signal by the synthetic one.

***Info*** button allows a verification of the linear filter (matrix):



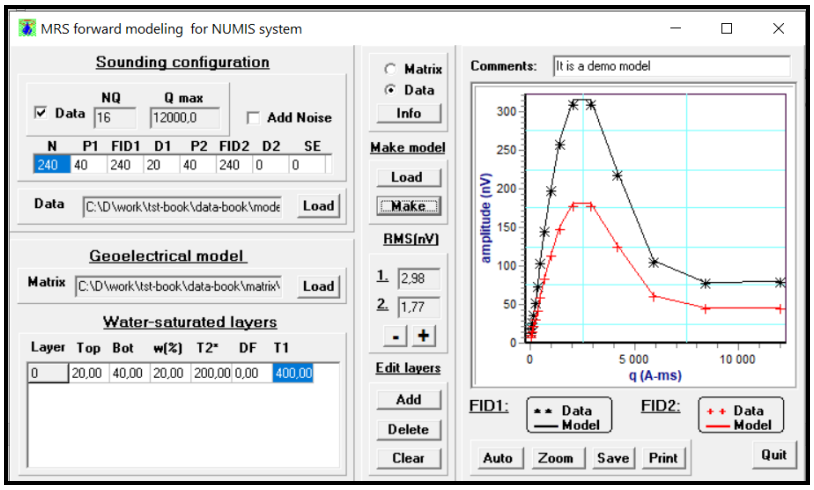

As well as the data summary provided by the inversion routine:




***Make model*** menu allows either to compute the set of synthetic data or to load previously saved model.

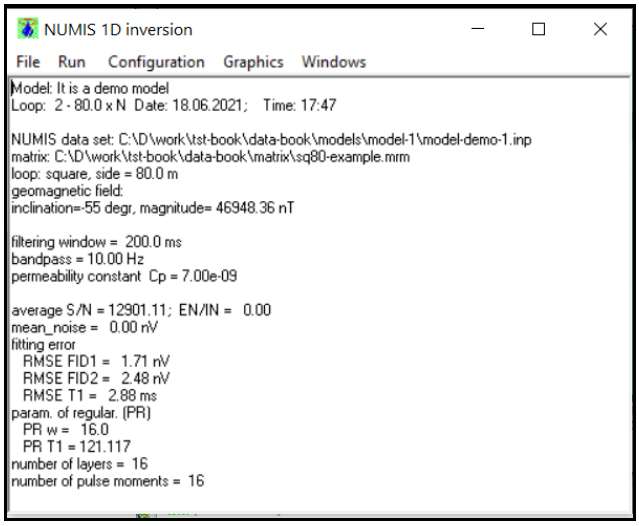
***Graphical*** menu in the right-hand side of the processing window allows visualizing synthetic and experimental signals. The graph can be scaled using the mouse buttons as well as ***Auto*** and ***Zoom*** buttons, saved (***Save***) and printed out (***Print***).

**Comments** window allows adding a short description of the model to the set of generated synthetic data.

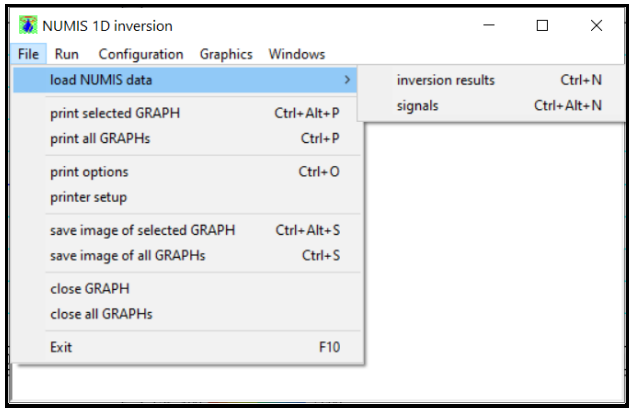

MRS forward modeling for NUMIS system
Sounding configuration
Data
NQ
16
Q max
12000,0
Add Noise
N P1 FID1 D1 P2 FID2 D2 SE
240 40 240 20 40 240 0 0
Data
C:\D\work\tst-book\data-book\mode
Load
Geoelectrical model
Matrix
C:\D\work\tst-book\data-book\matrix\
Load
Water-saturated layers
Layer Top Bot w(%) T2* DF T1
0 20,00 40,00 20,00 200,00 0,00 400,00
Matrix
Data
Info
Make model
Load
Make
RMS[nV]
1. 2,98
2. 1,77
-
+
Edit layers
Add
Delete
Clear
Comments:
It is a demo model
amplitude (nV)
q (A-ms)
FID1:
Data
Model
FID2:
Data
Model
Auto
Zoom
Save
Print
Quit

# Chapter 3. SAMOVAR 6x7: inversion

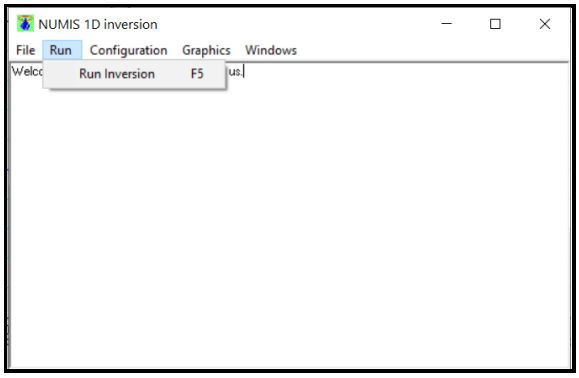
***Main window*** contains the menu bar and the text box. The focus can be set to this window by using the shortcut F3. The text box summarizes the data processing and inversion results. The menu bar running inversion and configuring the inversion workspace.



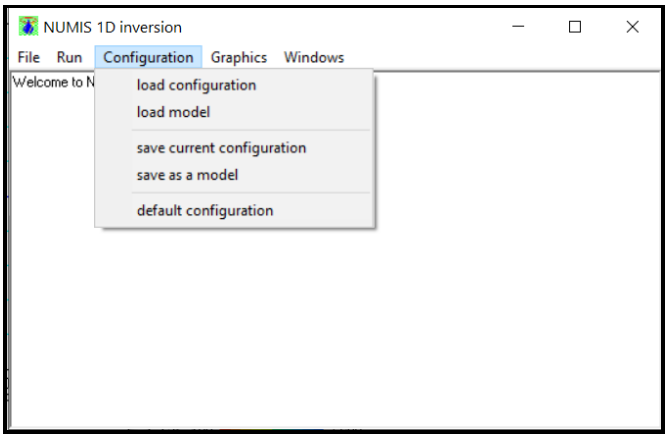

***File menu*** with the shortcuts allows loading recorded time series (signals) or results of the previous inversion, printing out or saving graphical representation of the inversion results and closing graphs. The F10 shortcut can be used for exit the inversion program.



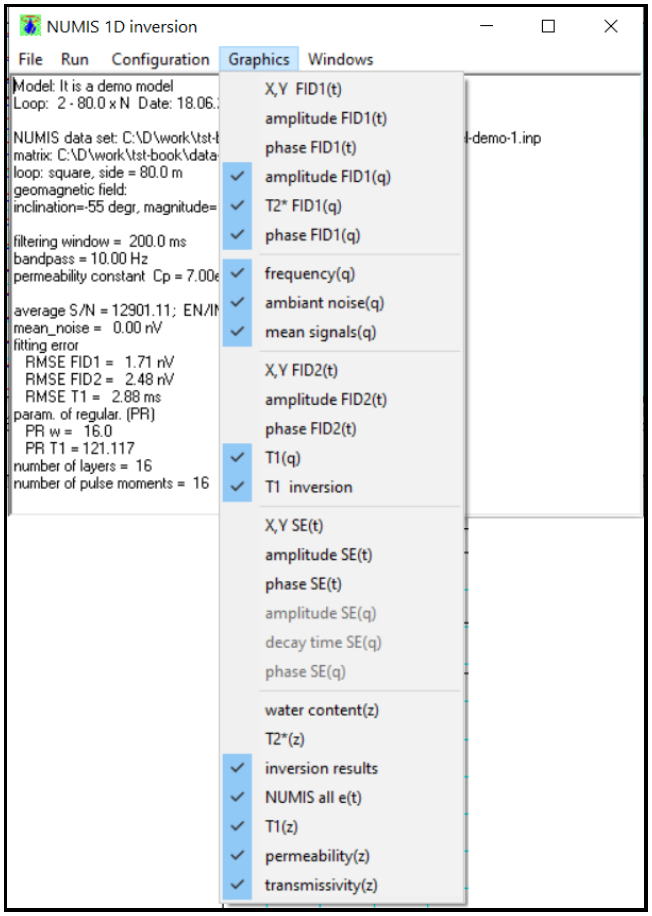

***Run menu*** allows starting inversion. SAMOVAR 6x7 program supports the amplitude inversion. Inversion of complex signals is not included in this version.



***Configuration menu*** allows saving and loading different configurations of the graphical windows in the workspace. Each configuration is automatically saved as the current configuration. Different configurations can be saved or loaded as specific models. The workspace can be configured by loading the current configuration, one of the previously saved models, or using the default configuration.

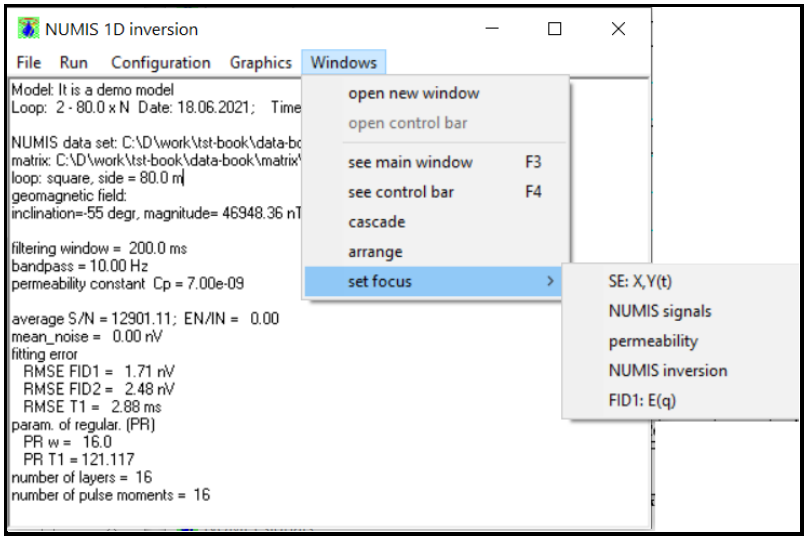



***Graphics menu*** allows appointing graphs to the selected by the mouse graphical window in the ***List*** mode or selecting graphs for using in the ***Roll*** mode.

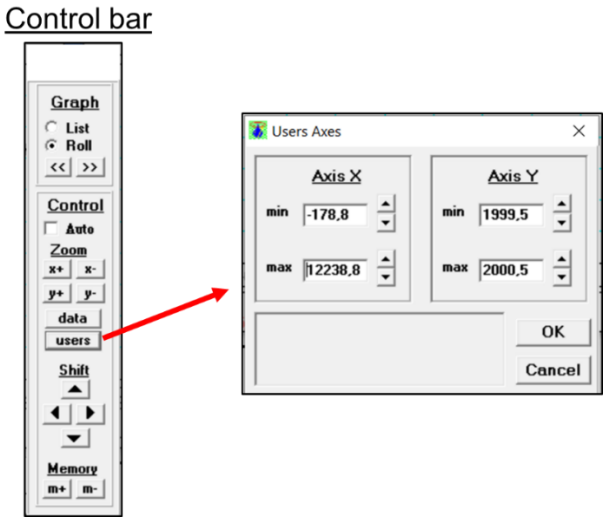



***Windows menu*** allows opening a new graphical window and setting focus on the main window (see ***main window***) or the control bar window (see ***control bar***). The graphical windows can be

shown as the ***cascade*** or side-by-side (***arrange***). The focus can be set on any active graphical window.



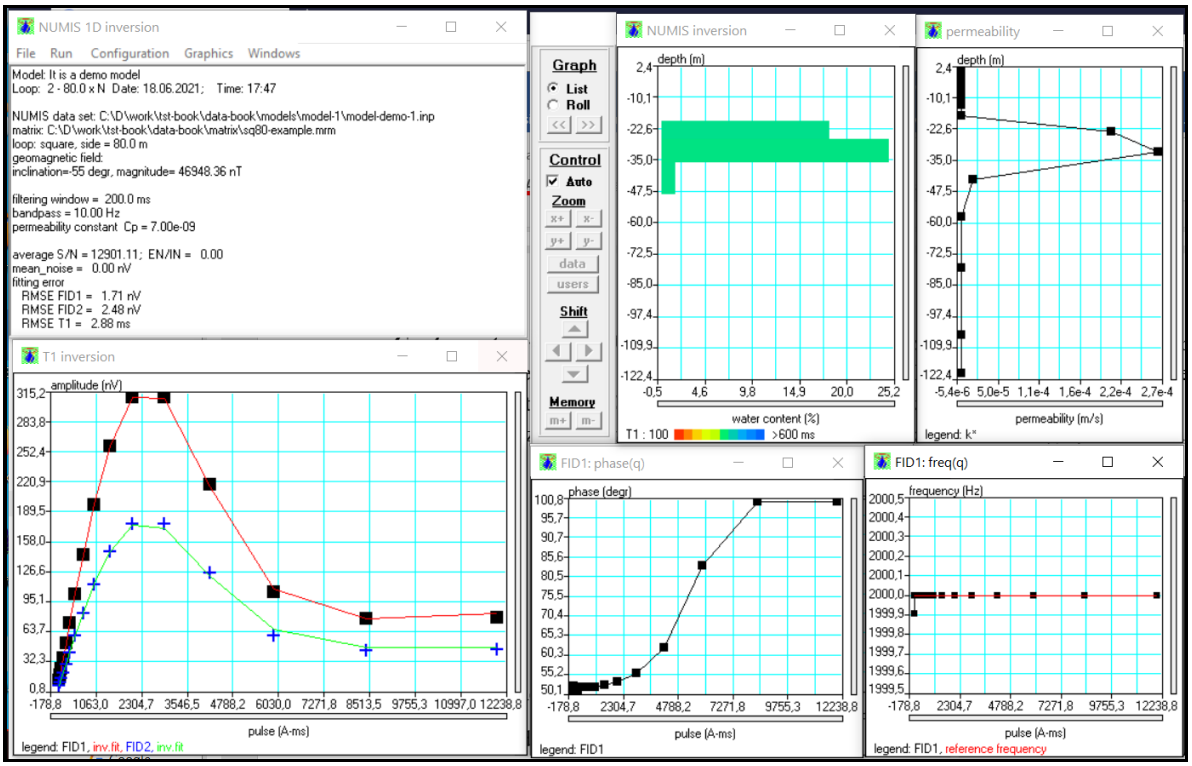

***Control bar*** window allows individually scaling graphs in the graphical windows. The shortcut to this window is F4. ***Graph*** option sets the ***List*** or the ***Roll*** mode for the selected graphical window. In the ***Roll*** mode, the pre-selected graphs can be shown in a sequence by using **<<** or **>>** buttons. For pre-selecting graphs in the ***Roll*** mode, one needs to set focus on one graphical window and to select with the mouse left button graphs exposed in the ***Graphics menu*** of the ***Main window***.

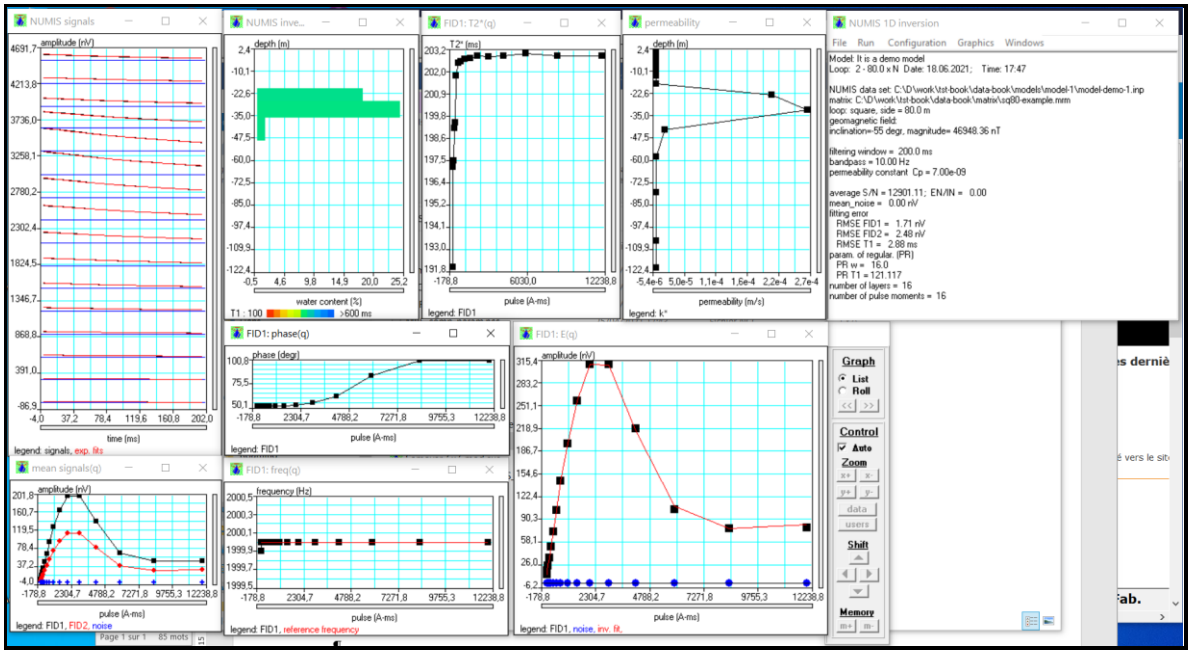



***Control menu*** allows scaling the graph in a focused graphical window. One can ***Zoom*** axes, set an automatic scaling (***data***) or set a user-defined scaling (***user***). In the focused graphical window, the graph can be shifted along the X and Y axes (***shift***). The current scale can be temporally saved and loaded using the ***Memory*** options (**m+** and **m-**). Note that the scale saved in the memory is not valid after exiting the program. For saving scaling on the hard disk use the ***Configuration menu***.

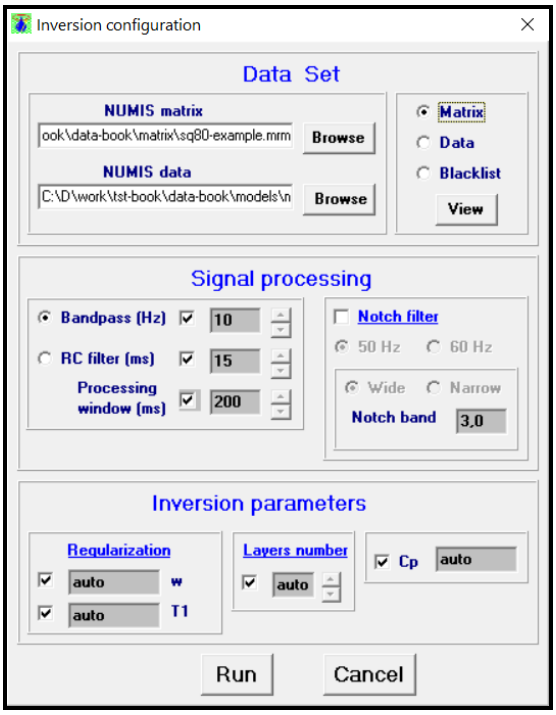
***Configuration of graphical windows*** in the workspace depends on the computer screen and the graphs the user wants to see when working with the inversion routine. Graphical windows can

be opened and closed using the ***Windows menu*** of the ***Main window***. Each graphical window can be individually sized and set on the screen. Size and location of the graphical windows can be saved using the ***Configuration menu***. The examples below show two different configurations.

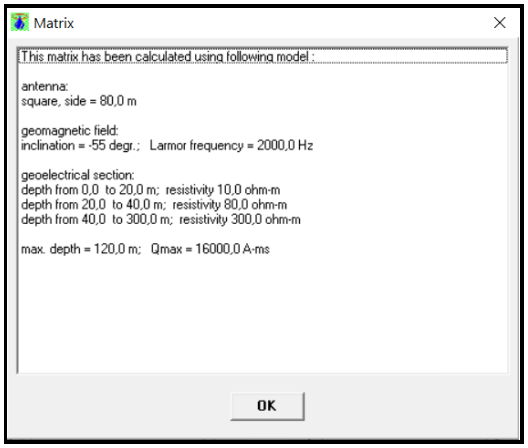


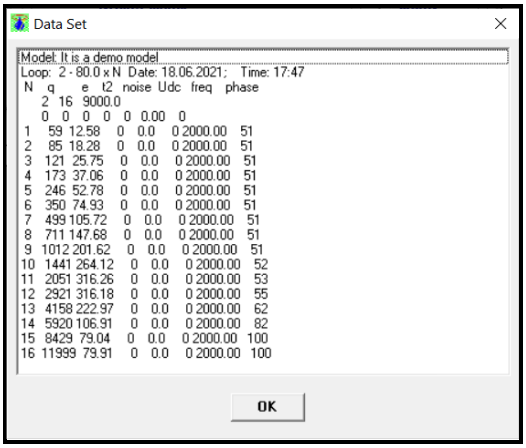



***Inversion configuration*** window allows guiding the data processing and inversion procedures.

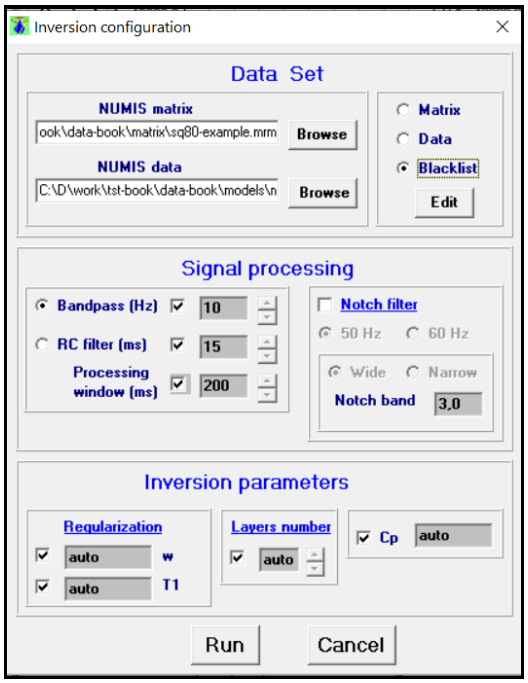


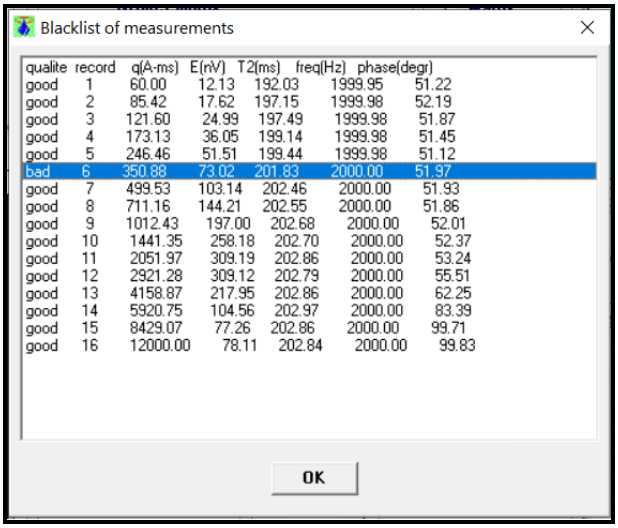

***NUMIS matrix*** (*name.mrm* file) and ***NUMIS data*** (*name.inp* file) have to be loaded using corresponding ***Browse*** buttons. Description of the ***Matrix*** (linear filter) or the ***Data*** set can be exposed for verification using the ***View*** button in the corresponding windows.




When working with real data, it may be necessary to exclude some measurements corrupted by noise or because of possible technical problem. For that, the corrupted record can be put to the ***Blacklist***. One can open the ***Blacklist of measurements*** window using the ***Edit*** button.



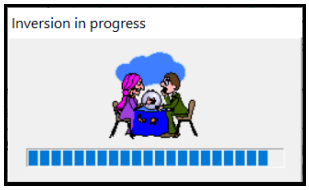



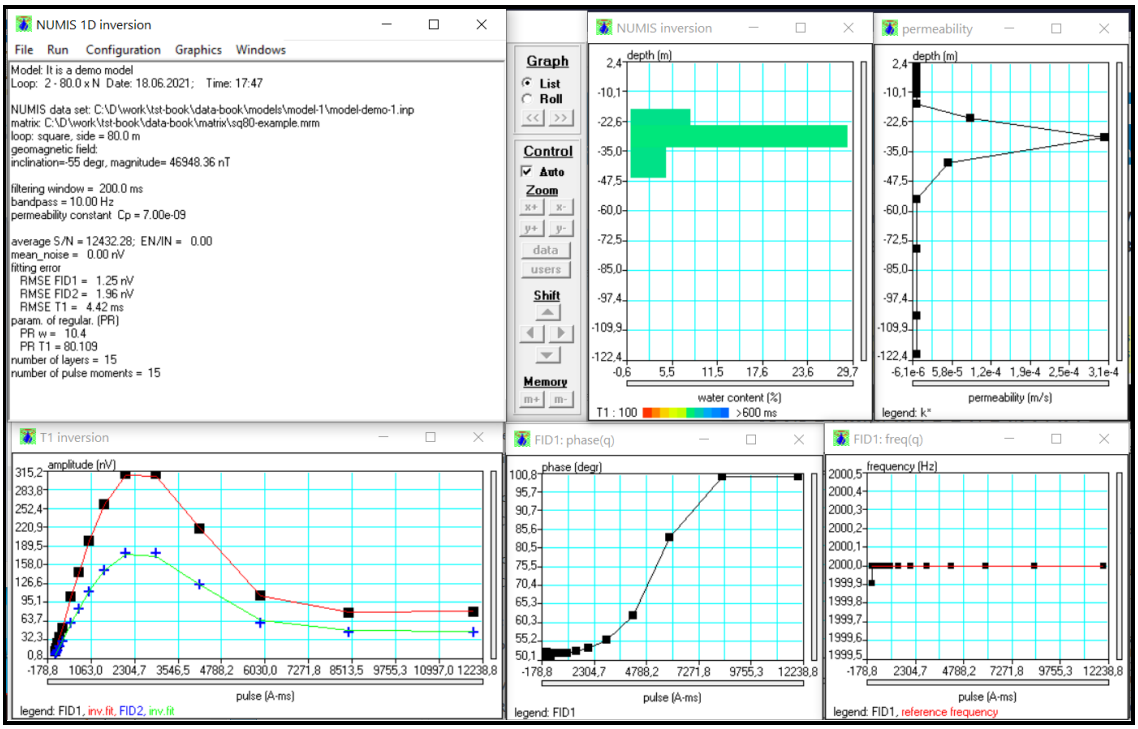

For blacklisting a record corresponding to one pulse moment, one has to double-click on the corresponding line in the ***Blacklist of measurements*** window. For example, the record in the line 6 corresponding to the pulse moment 350.88 A-ms shown in figure above is put in the blacklist and will not be considered by the inversion routine. For deleting the record from the blacklist, double-click this line again.

***Signal processing*** menu allows selection the ***Bandpass*** or ***RC filter*** with the corresponding bandwidth. MRS signal is processed considering the record length (***Processing window***) limited by the length of the field record. The ***Notch filter*** can be activated for ***50 Hz*** or ***60 Hz*** industrial frequency with the ***Wide*** or ***Narrow*** bandwidth.

***Inversion parameters*** menu allows selecting the regularization parameter in the Tikhonov regularization inversion for water content (***w***) or for relaxation time ($T_1$). The number of layers in the inverse model can be set automatically or manually (***Layers number***). For computing the hydraulic conductivity (permeability), the empirical constant $C_p$ may be set automatically or manually.

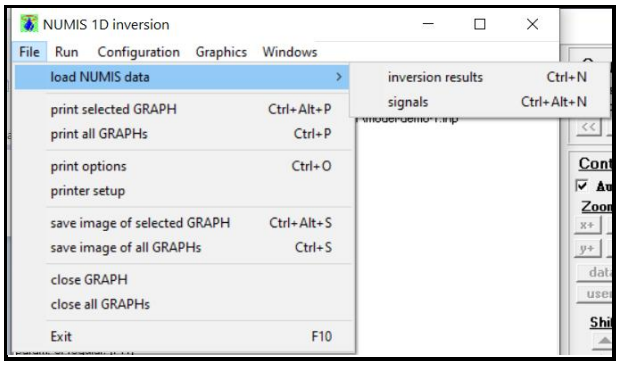
***Run*** inversion and analyze inversion results



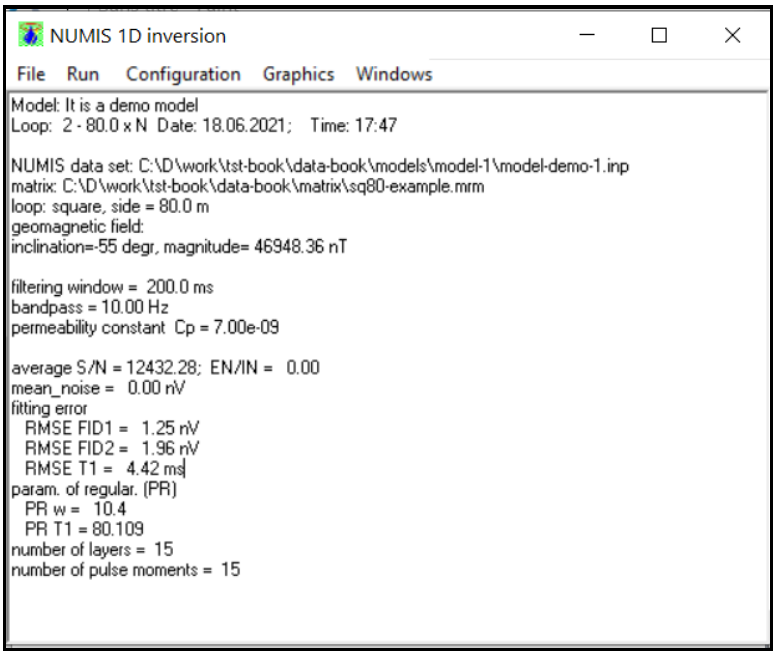



The inversion results are saved in the "*name.nov*" file. The summary of the inversion results is saved in the information file ("*name.nvi*"). A series of "*name.f01*", "*name.f02*", …, "*name.f016*" files contain filtered MRS records. Their number corresponds on the number of pulses.

For loading inversion results one can use the ***Main window*** menu. Note that if the graphical windows contain the graphs with the inversion results and with the MRS records then one needs to load the ***inversion results*** and then the ***signals***.

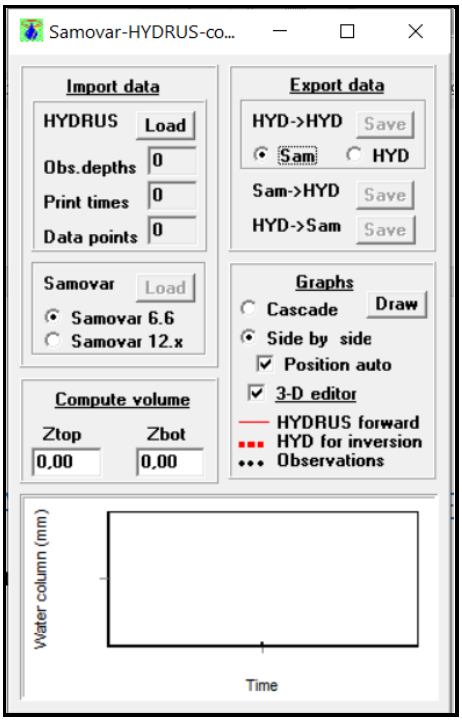



***NUMIS 1D inversion*** window contains the summary of the inversion parameters: signal processing parameter, estimate of the noise magnitude, average signal to noise ratio (S/N) and the external noise to the internal noise ratio (EN/IN), fitting error for the FID1 and FID2 signals, regularization parameter for $w$ and $T_1$ inversions, the number of pulse moment and the number of layers in the inverse model.


NUMIS 1D inversion
File Run Configuration Graphics Windows
Model: It is a demo model
Loop: 2 - 80.0 x N Date: 18.06.2021; Time: 17:47
NUMIS data set: C:\D\work\tst-book\data-book\models\model-1\model-demo-1.inp
matrix: C:\D\work\tst-book\data-book\matrix\sq80-example.mrm
loop: square, side = 80.0 m
geomagnetic field:
inclination=-55 degr, magnitude= 46948.36 nT
filtering window = 200.0 ms
bandpass = 10.00 Hz
permeability constant Cp = 7.00e-09
average S/N = 12432.28; EN/IN = 0.00
mean_noise = 0.00 nV
fitting error
RMSE FID1 = 1.25 nV
RMSE FID2 = 1.96 nV
RMSE T1 = 4.42 ms
param. of regular. (PR)
PR w = 10.4
PR T1 = 80.109
number of layers = 15
number of pulse moments = 15

# Chapter 4. SAMOVAR – HYDRUS convertor

***Main window*** shows the options to use for guiding the data exchange between SAMOVAR 6x7 and HYDRUS-1D programs.

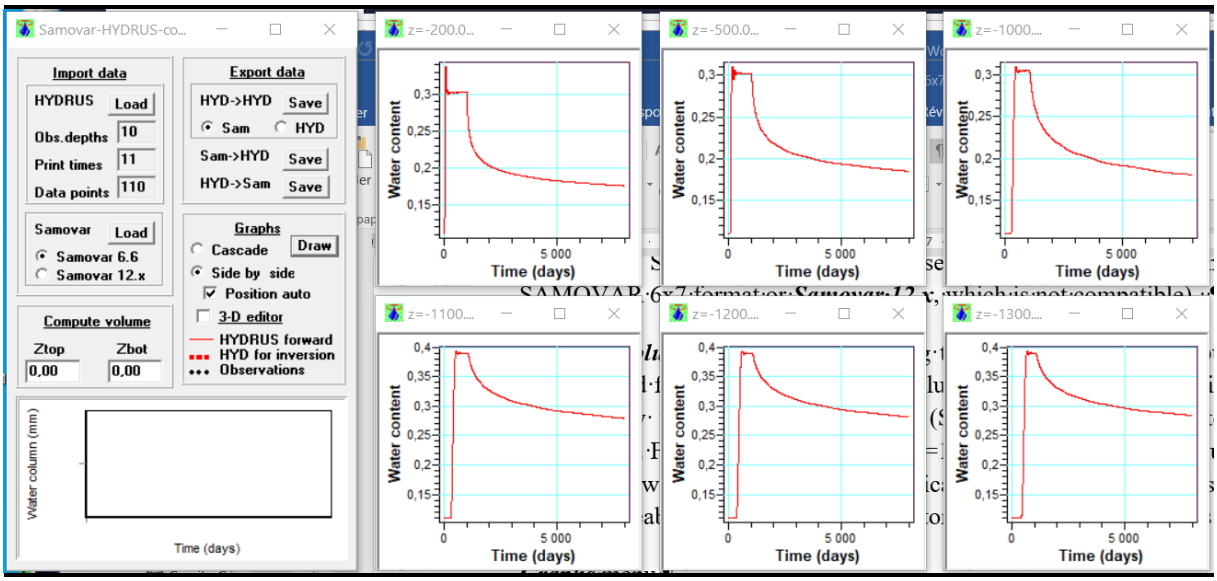


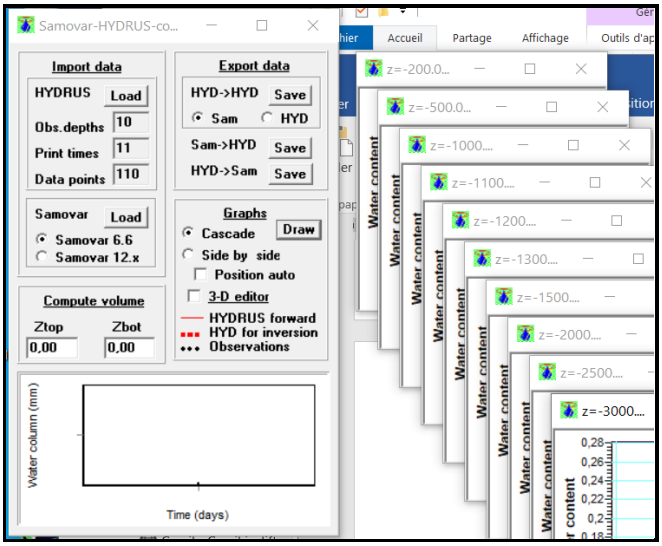

***Import data*** menu allows loading HYDRUS-1D or SAMOVAR 6x7 data sets. A short summary of the HYDRUS-1D data set contains information about the number of ***Observation depths***, the number of ***Print times*** and the number of ***Data points*** in HYDRUS-1D model. The number of data points is a product of the observation depth number and print times number. One should precise the SAMOVAR version to use (***Samovar 6.6*** data format is compatible with SAMOVAR 6x7 format or ***Samovar 12.x***, which is not compatible).

***Compute volume*** menu allows selecting the depth interval to compute the equivalent water column used for estimating the water volume in the subsurface considering the water content provided by the MRS inverse model (SAMOVAR) and the water flow forward model (HYDRUS). For example, $z_{top}$=2 and $z_{bot}$=12 means that the water column will be computed in the layer between 2 and 12 m. The graphical window below visualizes the water columns. This graph is sizeable by using the mouse buttons. The double click makes an automatic scaling.

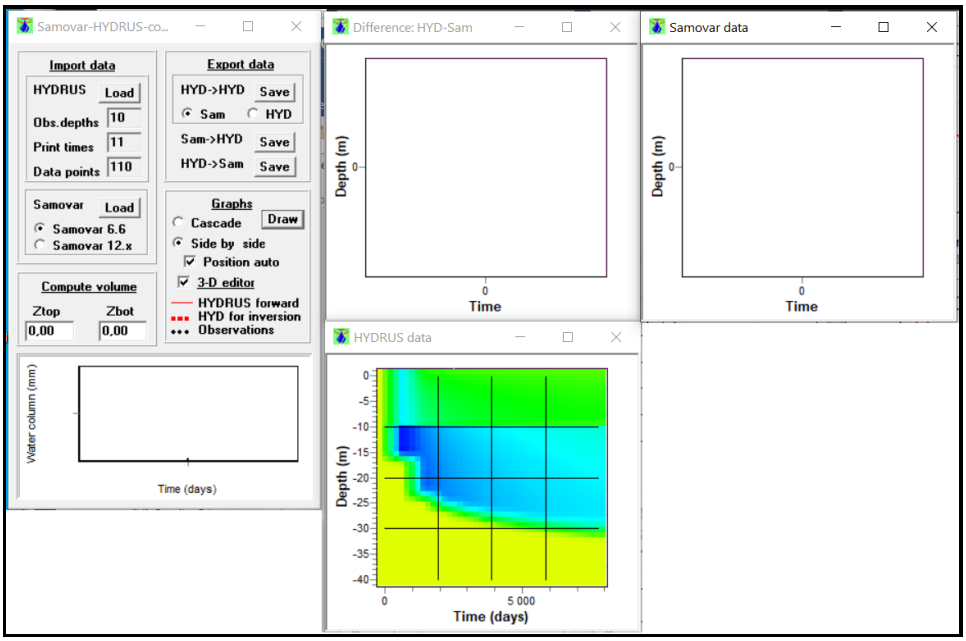
***Graphs*** menu allows configuring graphs that visualize SAMOVAR and HYDRUS water contents. If the configuration is changed, then the graphs have to be actualized by using the ***Draw*** button. The water content versus time corresponding to the depth of the observation points in HYDRUS modeling are plotted in graphical windows. Each window contains three graphs: ***HYDRUS forward***, ***HYDRUS for inversion*** and ***Observations***. HYDRUS forward shows the water content given by the model, HYDRUS for inversion shows the water content corresponding to observations at the observation point that can be used for the inversion using the HYDRUS inverse modeling routine and Observations show SAMOVAR provided water

content at the depth corresponding to the observation points. The number of these windows is equal to the number of the observation points. The graphical windows can be exposed ***Side-by-side*** or in ***Cascade***.

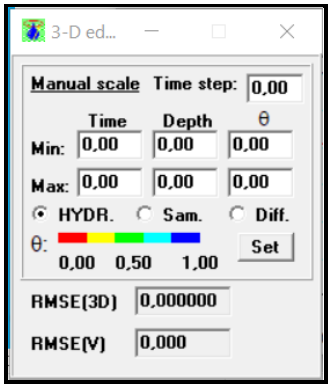



If the ***3-D editor*** is activated, then the HYDRUS and SAMOVAR water contents and the difference in-between are shown in three corresponding windows. If ***Position auto*** is deactivated, then the size and the position of each graph are defined manually.

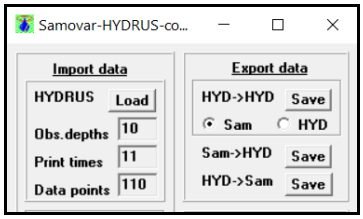



***3-D editor*** window allows setting the time step for plotting the water content graphs. For accelerating the water content visualization, it is recommended to use larger time steps. It could be particularly useful when working with a slow computer.



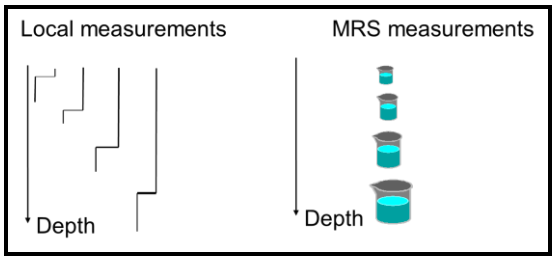

When selecting one window (***HYDRUS***, ***Samovar*** or ***Difference***), the color scale corresponds to the selected graph. For setting a manual scale in the selected graph, set the ***Min*** and ***Max*** values and push the ***Set*** button. For the automatic scaling, double-click on the selected graph. ***RMSE(3D)*** and ***RMSE(V)*** show respectively the root-mean-square error (difference) computed considering the water content profiles and the water volume (water column) versus time graph plotted in the ***Main window***.

***Export data*** menu allow data exchange between SAMOVAR and HYDRUS.

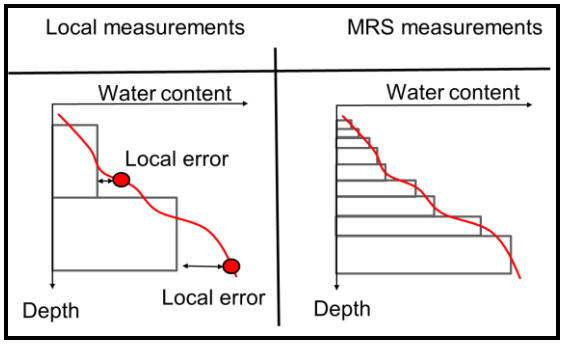


***HYDRUS-HYDRUS*** option allows recording the water content provided by HYDRUS forward modeling and corresponding to the HYDRUS observation points to HYDRUS (***Save***). These data can be used as input data in the inverse modeling with the HYDRUS inversion routine. If ***HYD*** option is set, then data are transferred without modification. This option can be useful for testing HYDRUS inverse modeling. If ***Sam*** option is set, then data simulate MRS measurements of the water content computed based on the HYDRUS water content. Correction comprises a delay between HYDRUS provided water content and that shown by MRS. This option allows testing HYDRUS inversion using MRS data at the observation points.

Correction of the MRS water content for a direct comparison with the HYDRUS provided water content is necessary because of different scales and different resolution for HYDRUS and MRS results. The water flow model computed with HYDRUS shows an instant water content at the local scale. With local measurements one observes progressing infiltration front and MRS shows the volume of accumulated water.

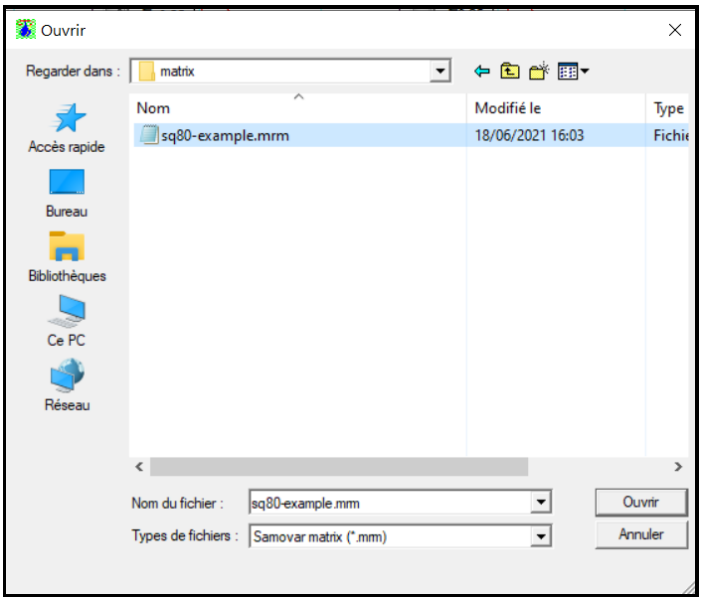



Measurements of the water volume instead of the instant value of the water content may cause a delay between the infiltration front and the volume observed with MRS and the local errors, as shown in the figure below (left-hand graph). In this example, the red line shows the true water content and the black line shows the MRS estimated water content.

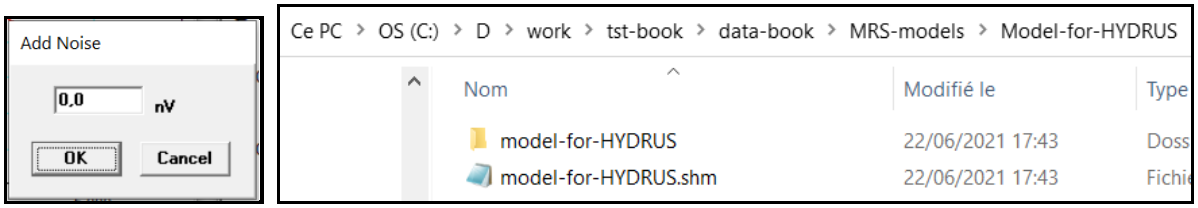



However, local errors can be neglected at larger scale and MRS provides a reasonable approximation of the water content (right-hand graph).

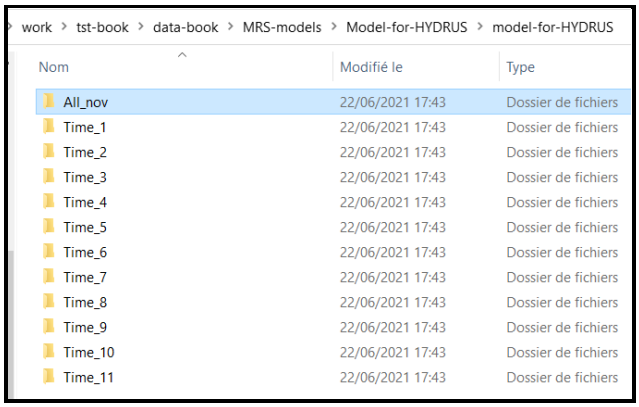
***Samovar->HYDRUS*** option allows transferring MRS measured water content to HYDRUS (***Save***). The MRS water content is used as the initial water content for the water flow modeling. ***HYDRUS->Samovar*** option performs the MRS forward modeling using the water content given by HYDRUS (***Save***). For that, the linear filter (matrix) has to be computed using ***SAMOVAR computing*** program and loaded.

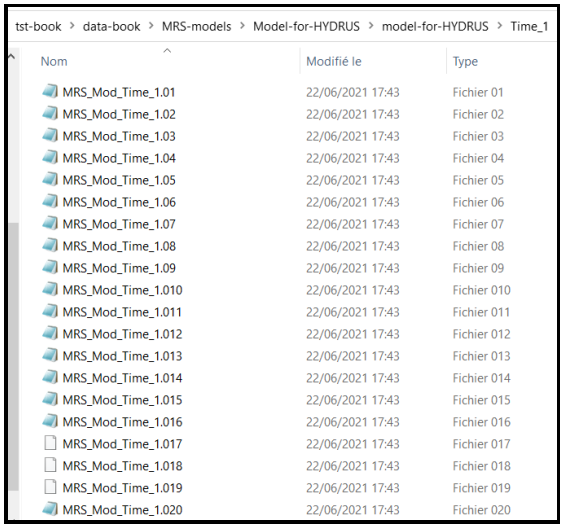



A random noise can be added to MRS records. A set of synthetic MRS data simulating field measurements will be automatically created.

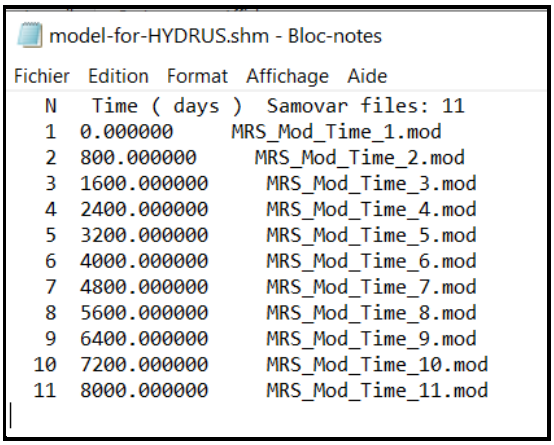



MRS dada set is composed of the "*name.shm*" file and the record files containing MRS records corresponding to each sounding.



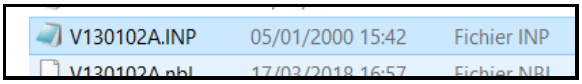




The summary file "*name.shm*" contains a summary of MRS data file names and the measuring time corresponding to each sounding.

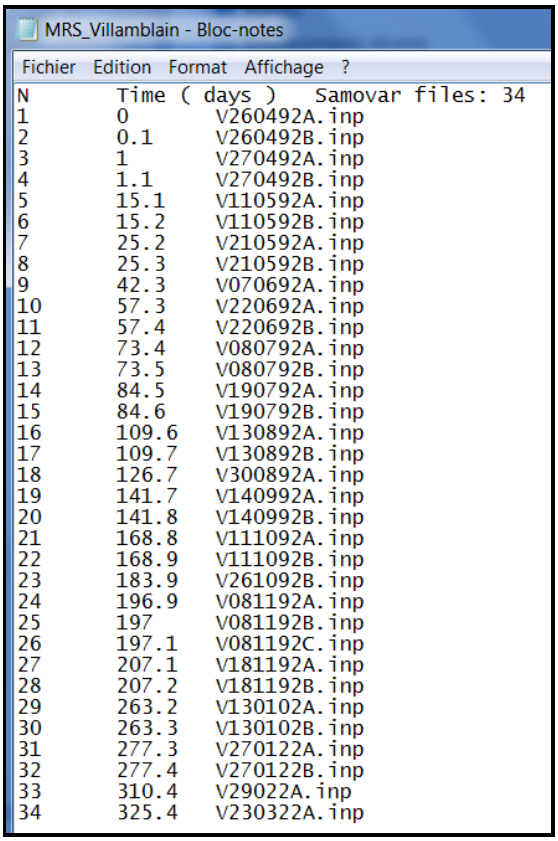



***SAMOVAR inversion*** program allows computing the inverse models (*Time_1*, *Time*_2 etc) to use for the water flow modeling with HYDRUS.

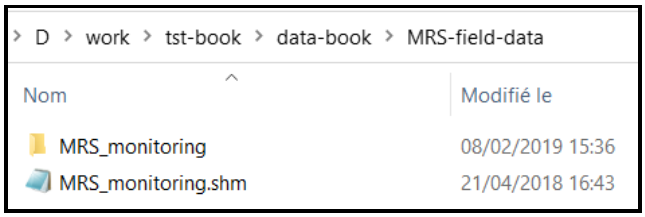
***MRS field data*** also can be used with the ***SAMOVAR – HYDRUS convertor***. For that, a field data set has to be manually prepared in the same format as the synthetic data set. Information about the measuring time corresponds to the time of the "*name.inp*".

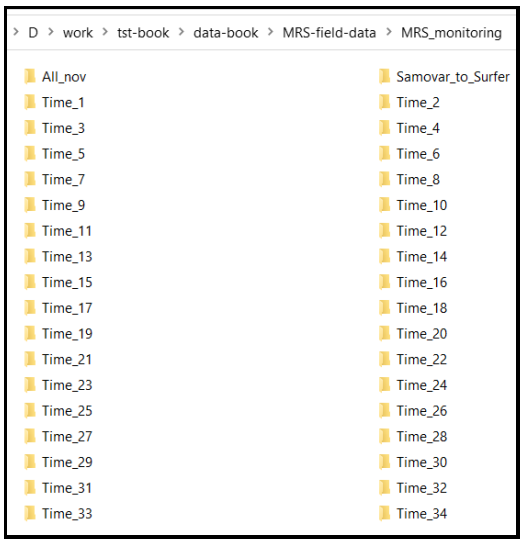



For example, the data set contains 34 soundings. Using a text editor, create a file "*name.shm*" (take care to respect the blank positions):

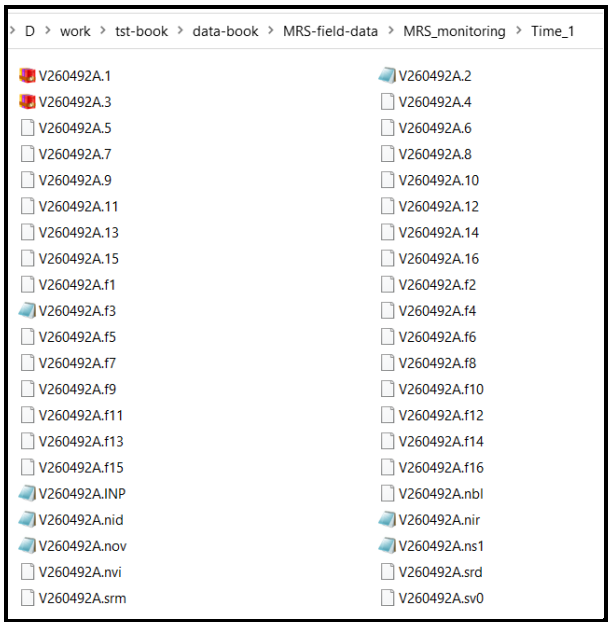


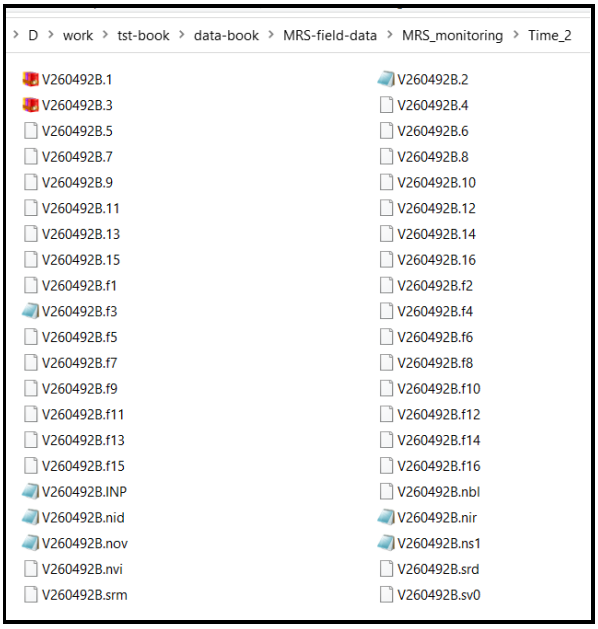
Make MRS 1-D inversion of all the soundings. Create 34 folders named from "*Time_1*" to *Time_34*".




Copy all the files corresponding to one sounding in one folders "*Time_N*". Example below shows the data sets in the folders "*Time_1*" and "*Time_2*".




Note that folders "*All_nov*" and "*Samovar_to_Surfer*" will be created and filled up automatically by ***SAMOVAR – HYDRUS convertor***.

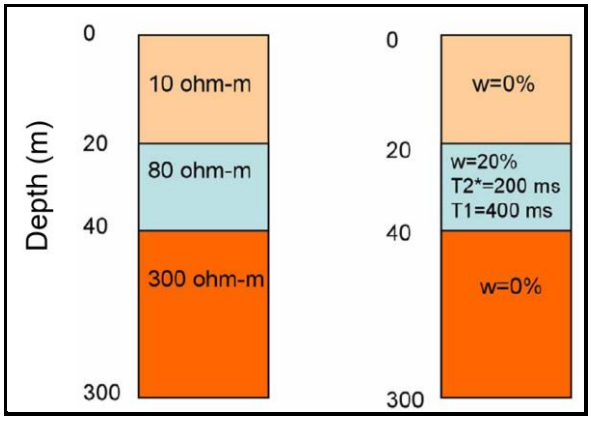
When modeling a water flow with HYDRUS-1D using MRS data, the final time in the hydraulic model should be set equal to the last day of the MRS monitoring and the number of print times should be set *N-1* where *N* is the number of MRS soundings. The first sounding is used for setting the initial water content.

# Chapter 5. Getting started

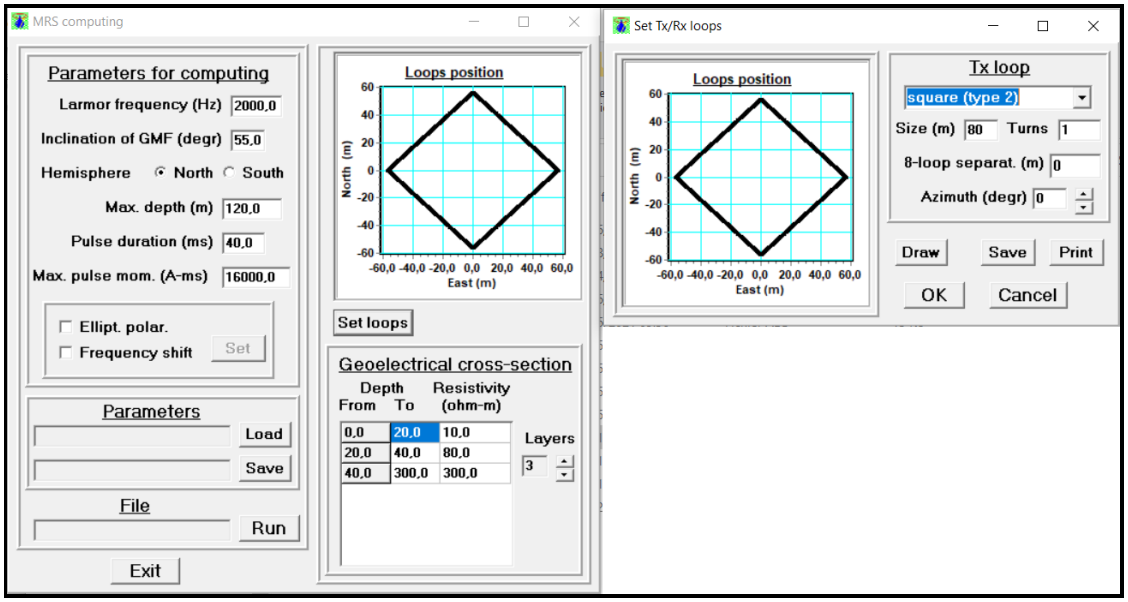
## MRS forward modeling

Let us assume the following modeling conditions:

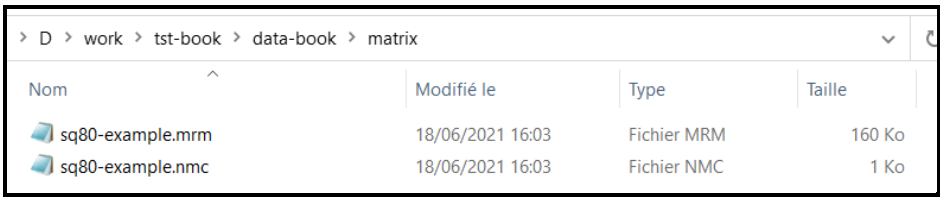
- A 80 m-side square MRS loop (the max depth of 120 m).
- FID sounding with two 40-ms pulses with the max pulse moment of 12000 A-ms.
- The geomagnetic field inclination 55°N, magnitude 46948 nT (the Larmor frequency of 2000 Hz).
- The geoelectrical cross-section and parameters of the water saturated layer are given below:



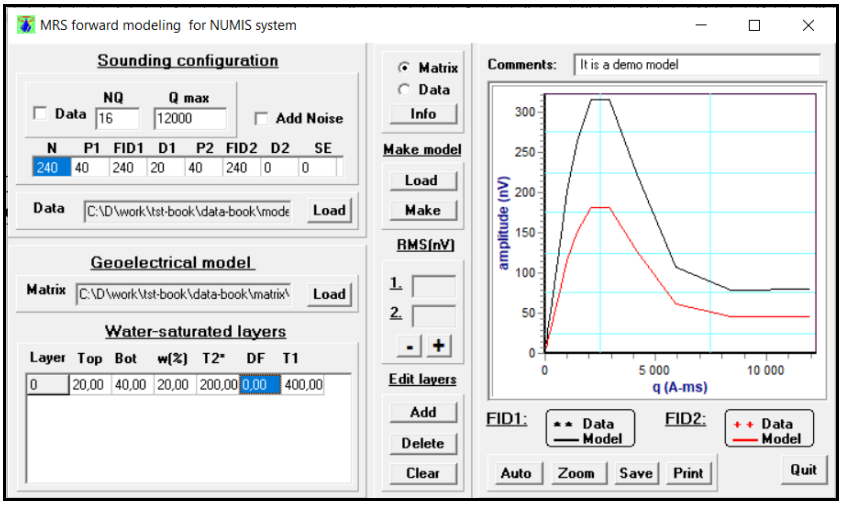

We compute the linear filter corresponding to the geology and the geographical position of the investigated area with ***SAMOVAR computing*** program



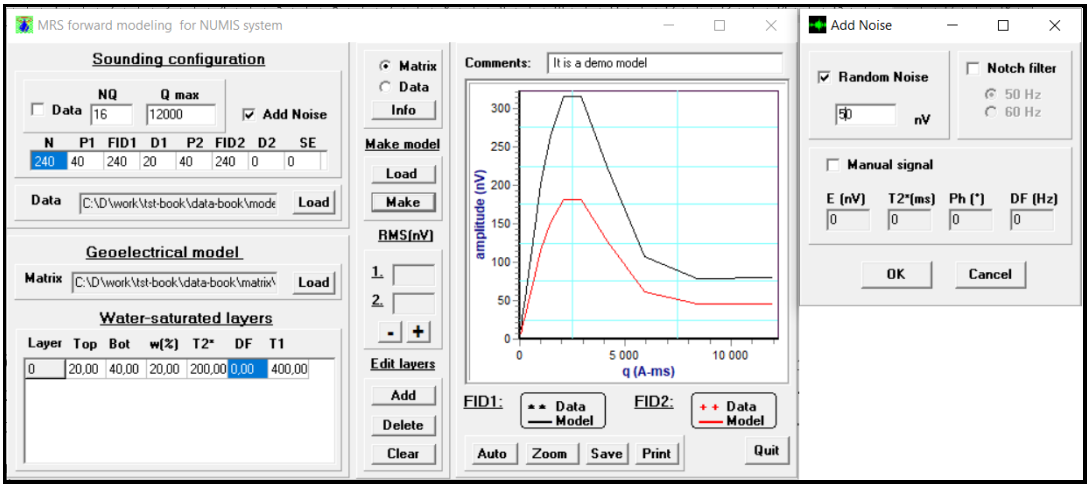

The linear filter is stored in two files



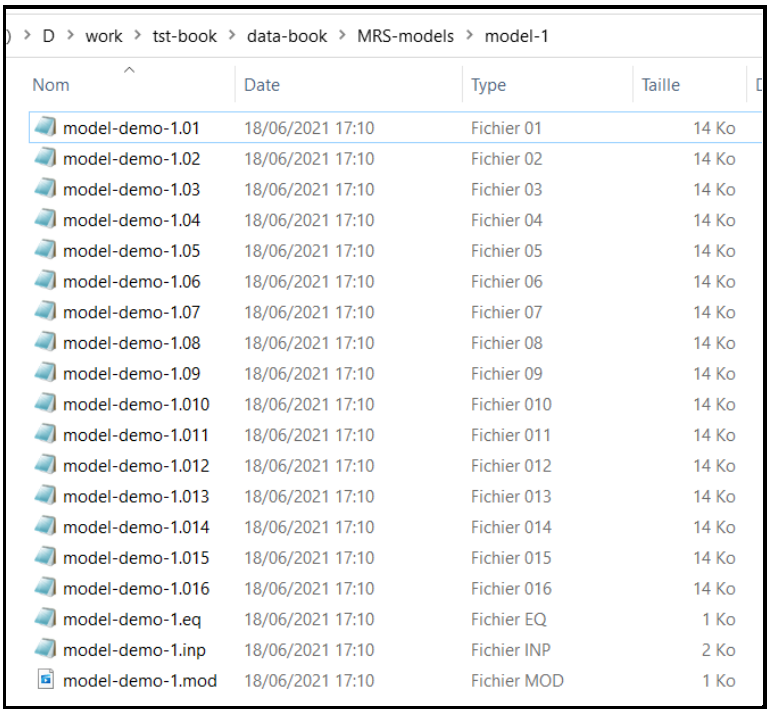

The linear filter represents measuring conditions. For computing MRS signals we use the ***SAMOVAR forward modeling*** program.




We load the linear filter (matrix), one water saturated layer corresponding to our model and compute the MRS signal by double clicking on the water saturated layer. Then, we create the data set simulating field measurements (***Make***) and add 50 nV of the ambient noise.

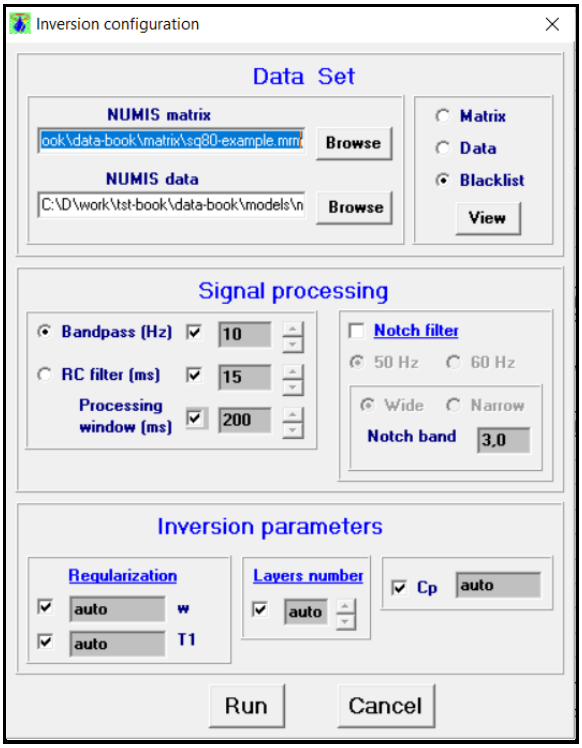



The data set composed of 19 files (for this model) is saved in the selected folder.

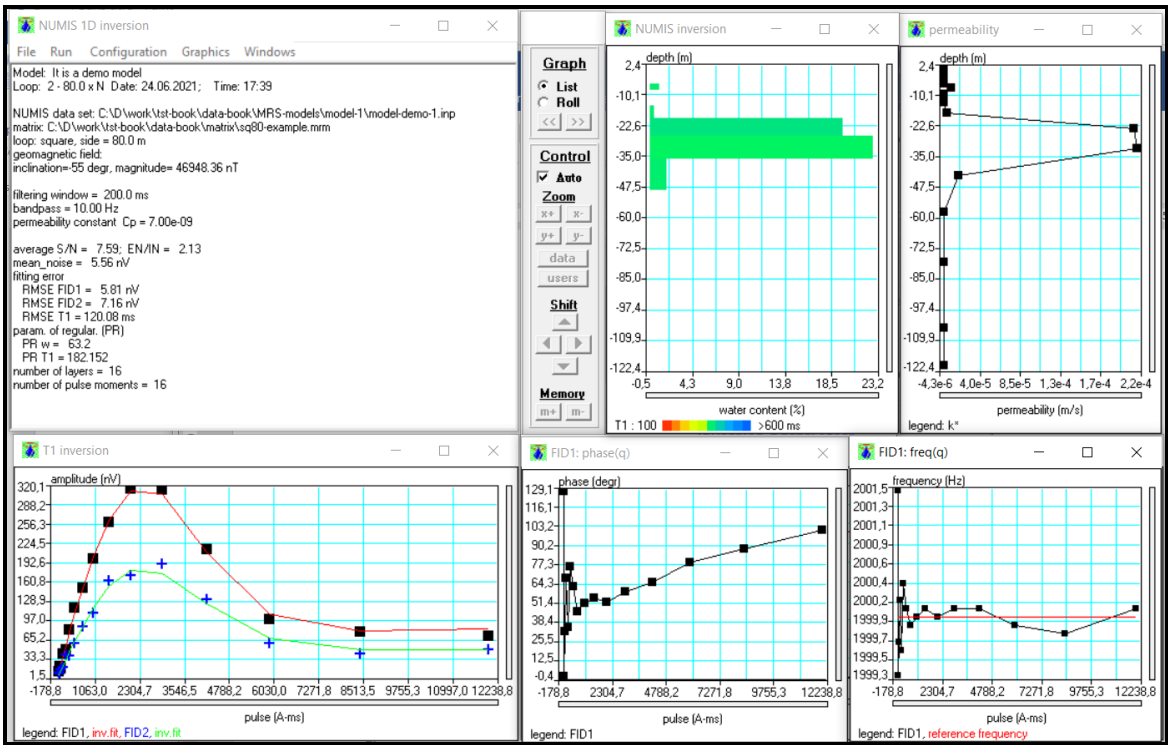


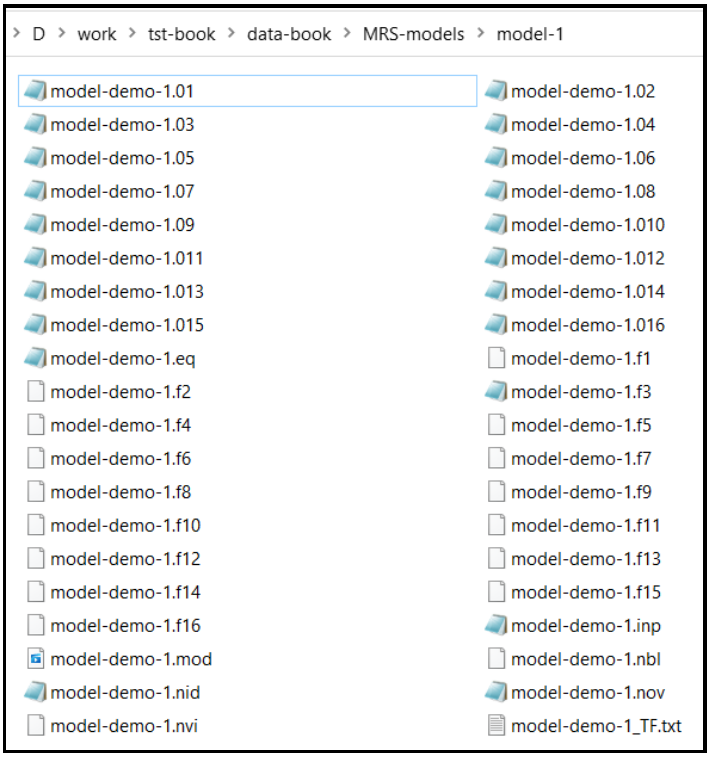

## MRS inversion

For this example, we use the synthetic data set created in the previous section. MRS data set is composed of many filed that are headed by the "*name.inp*" file. In this example, the data set is "*model-demo-1.inp*". We load the data and the linear filter. For the records processing and inversion option we use automatic options with the default parameters.

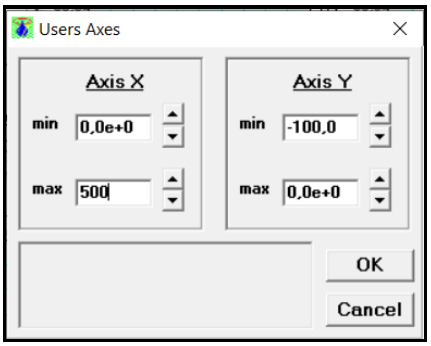


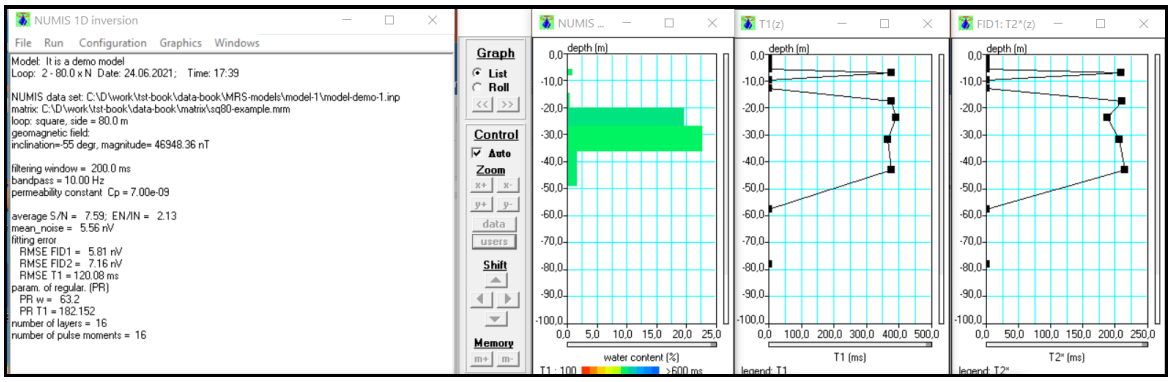

Inversion results are shown by using the user selected graphical windows and save on the hard disk in the same folder with the data set.

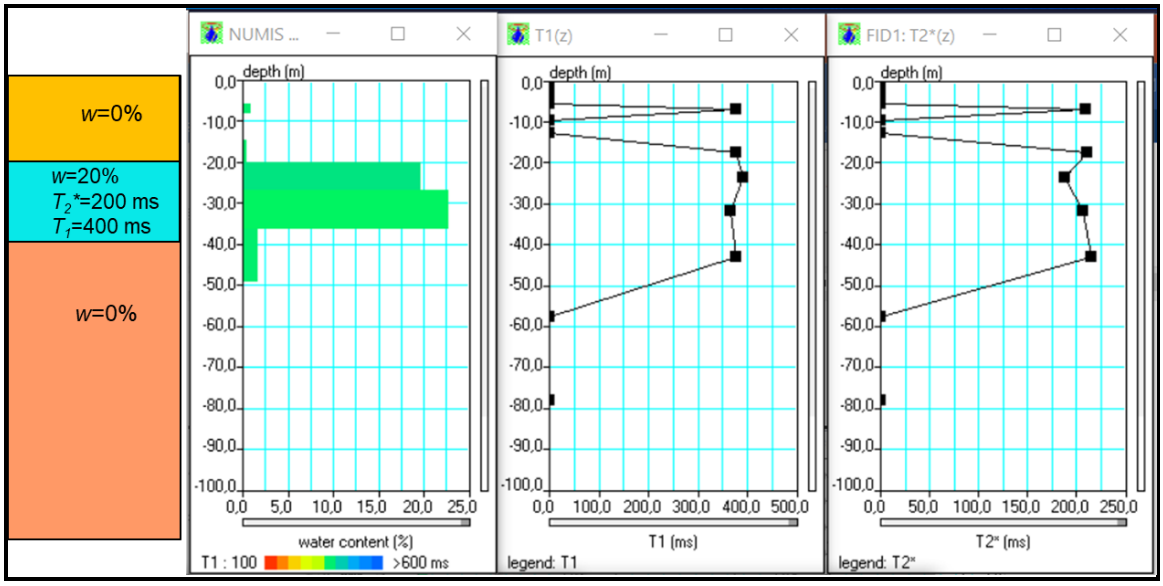



Working with synthetic data we can compare the initial model and the inverse model being the final result of MRS inversion. For reports, it is often convenient to manually define axes and graphs.

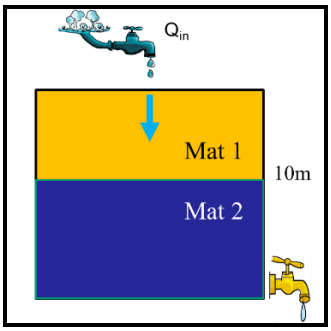



## MRS and water flow modeling

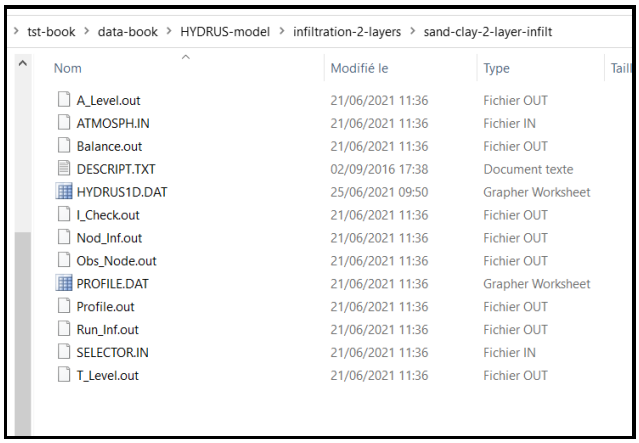
For this example, we created a water flow model using HYDRUS-1D program. The model comprises two layers with different hydraulic properties. Both layers are unsaturated. The rainfall varies during the monitoring time (8000 days) and we have 11 MRS soundings (one sounding performed with an interval of every 800 days).



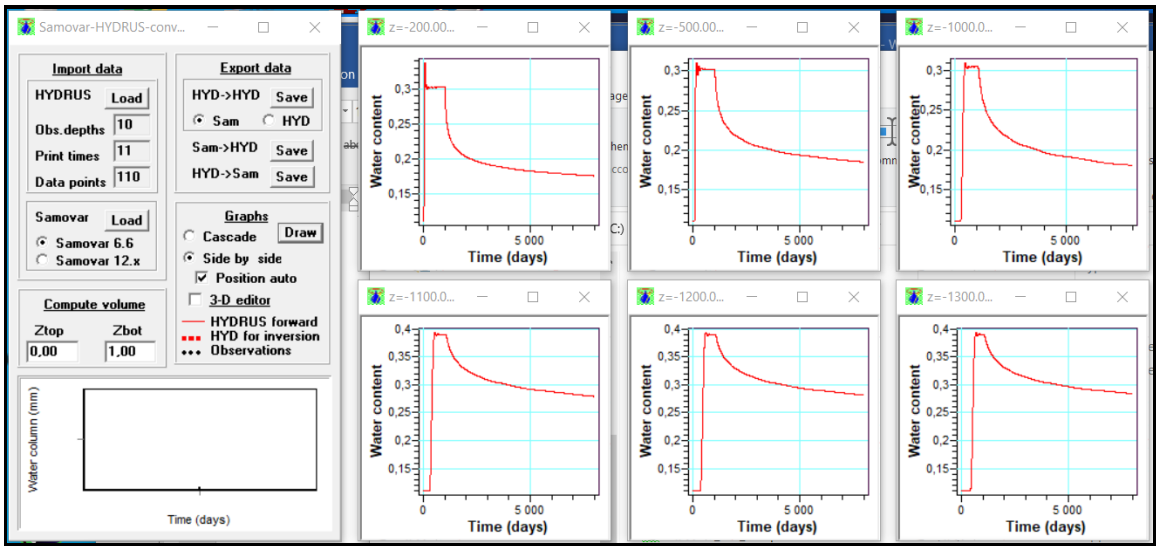

MRS measuring setup

- Tx/Rx loop: square 80x80 m, 1 turns
- Geomagnetic field: 55°N,
- Larmor frequency 2000 Hz
- Max. pulse moment: 12000 A-ms
- Pulse duration: 40 ms
- Number of pulses: 20
- Subsurface: 100 ohm-m half-space

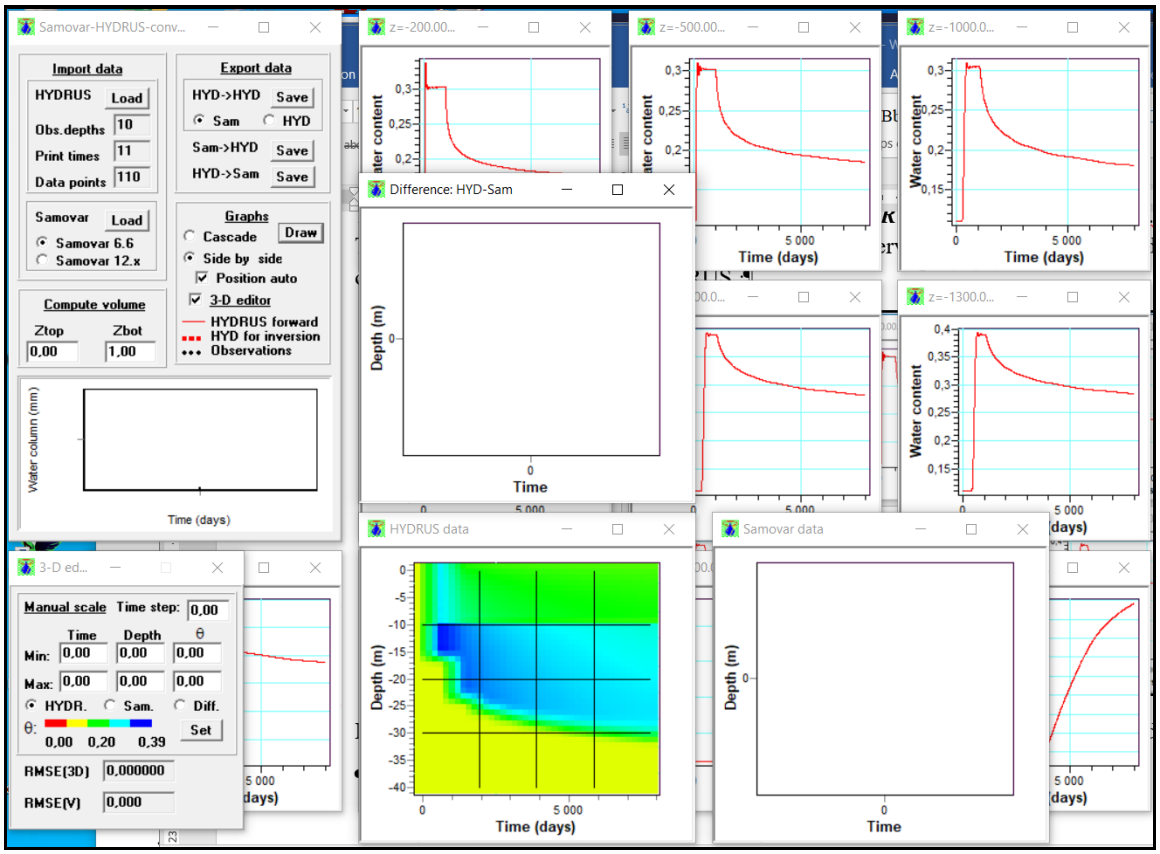
The water flow model is saved in the folder created by HYDRUS-1D.



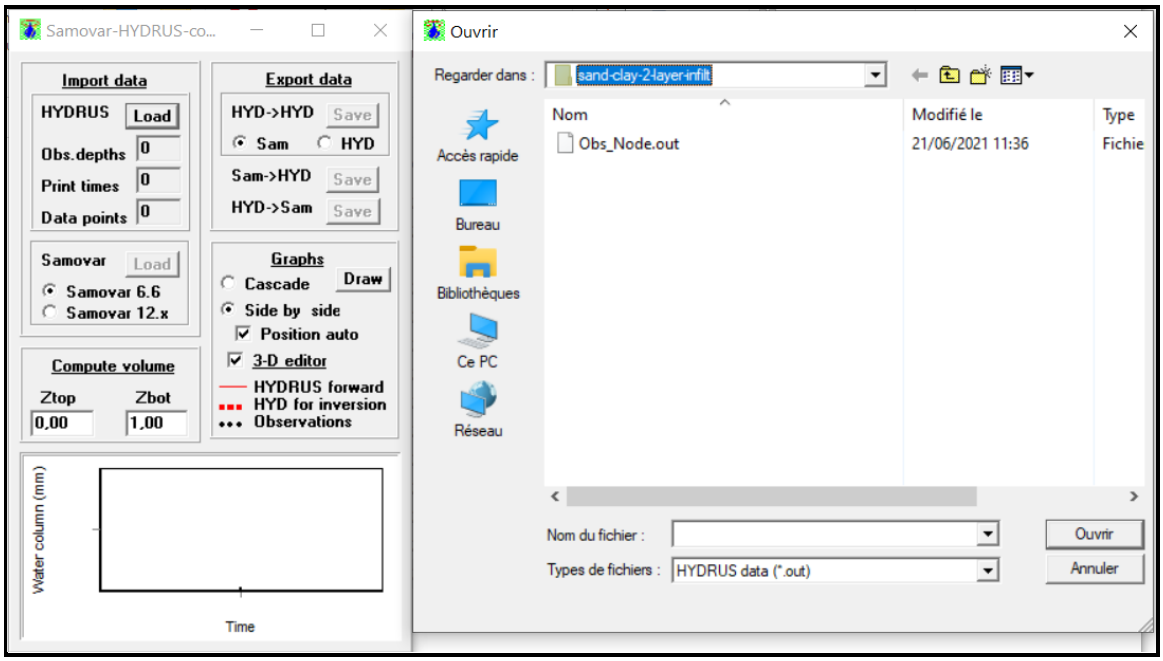

This model should be loaded with the ***SAMOVAR - HYDRUS convertor*** ("*name.out*" file). The water content provided by HYDRUS-1D can be observed at the depth corresponding to the observation points defined in HYDRUS.

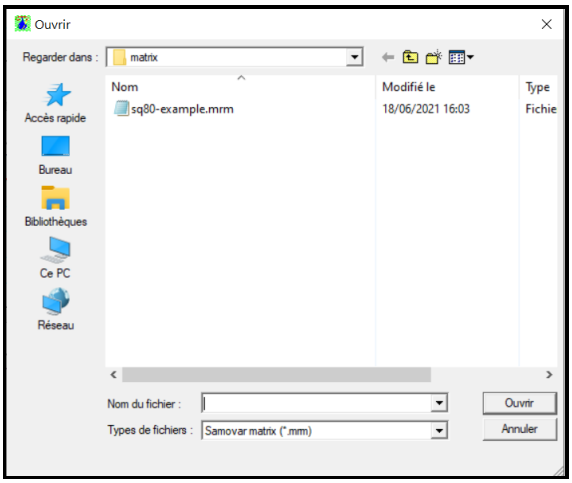


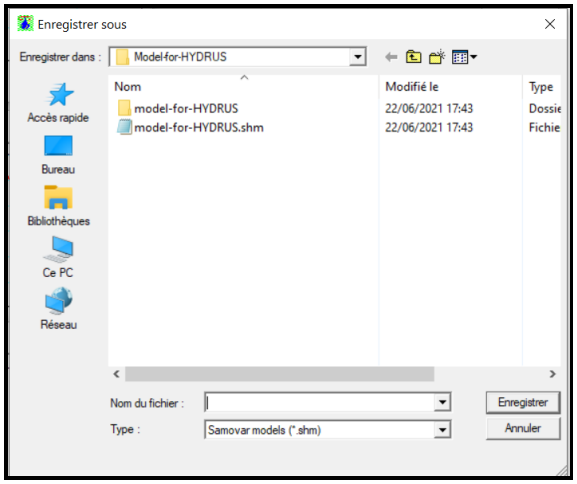

If the 3-D editor is activated, then the plot of the water content can be also visualized.




Then, a set of files simulating SAMOVAR 6x7 measurements computed considering the HYDRUS provided water content can be created using the ***HYD->Sam Save*** button. This is done in two steps: the liners filter corresponding to the MRS measuring setup is loaded and then the data set is saved on the hard disk.

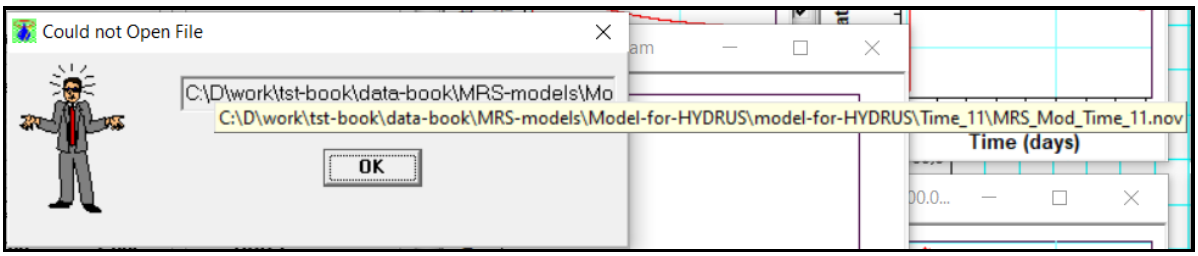




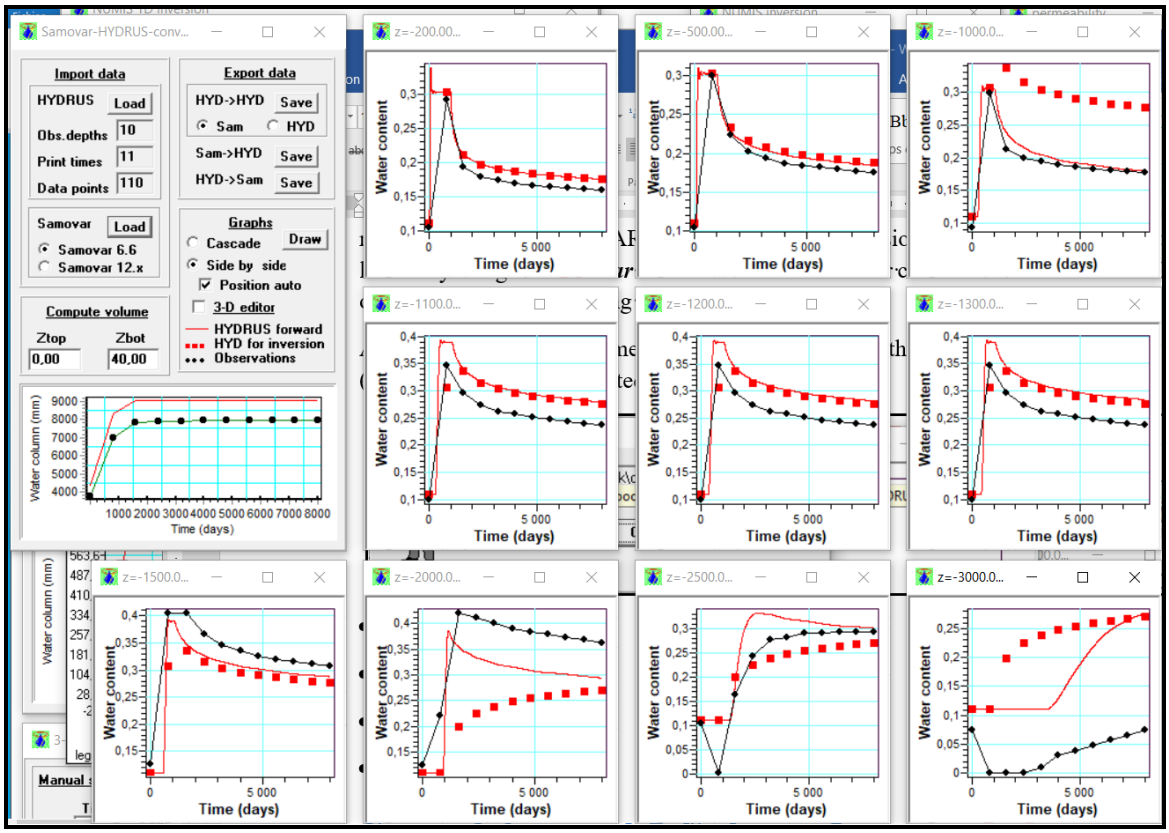




For loading MRS water content, MRS measurements have to be processed using the ***SAMOVAR inversion*** program. Each sounding is processed individually. The time-lapse inversion is not supported by SAMOVAR 6x7 version. When inversion is done, MRS water content can be loaded by using the ***Samovar 6.6 Load*** button. The water content can be visualized at HYDRUS observation points and using the ***3-D editor***.

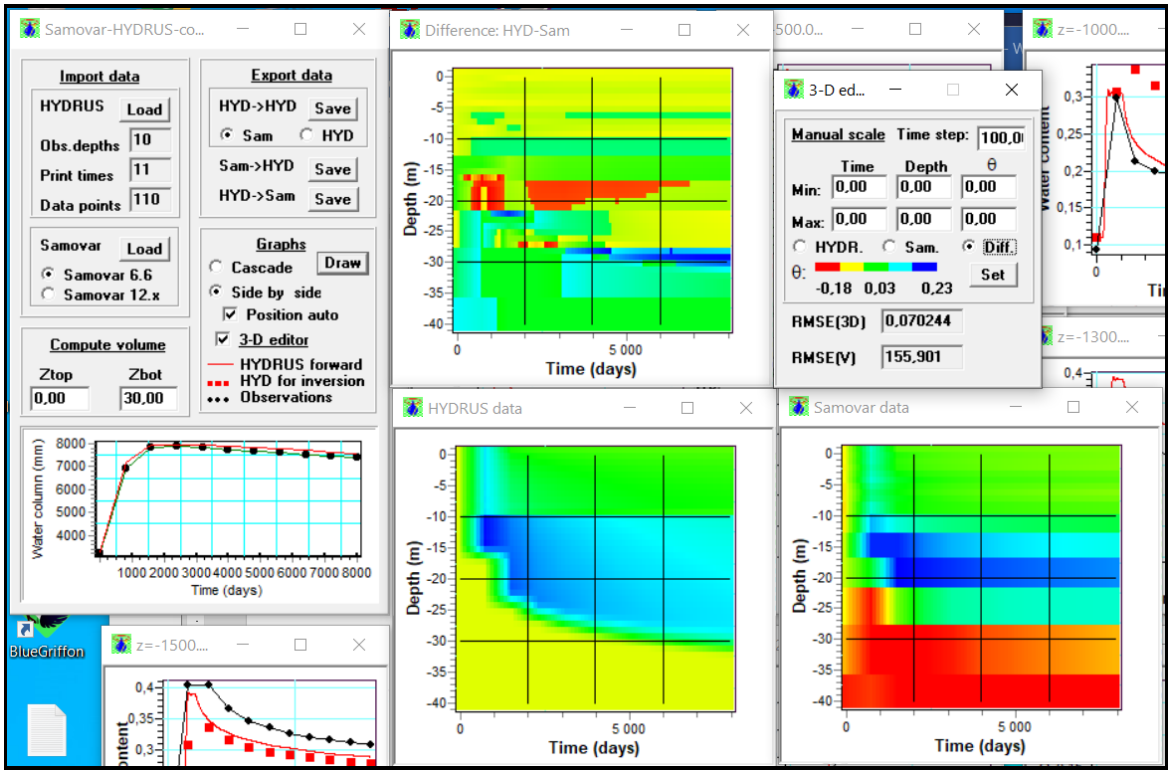
An example of the error message shown below says that inversion of one of the sounding (Time_11) was not completed.




Set the depth interval for computing the water column (***Compute volume***) and compare the HYDRUS and SAMOVAR water column. The water content at the observation points is shown in the graphical windows. The red squares show the HYDRUS water content corrected considering the difference between the MRS and water flow modeling. Note that if the hydraulic model is changed, then the water contents for both HYDRUS and SAMOVAR have to be reloaded. If visualization or the depth interval for computing the water column are changed, then SAMOVAR data have to be reloaded.

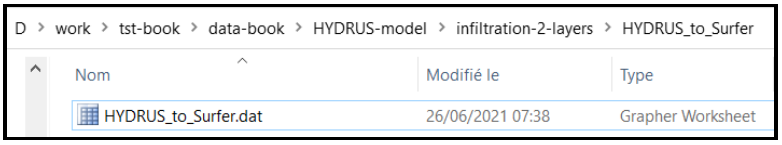


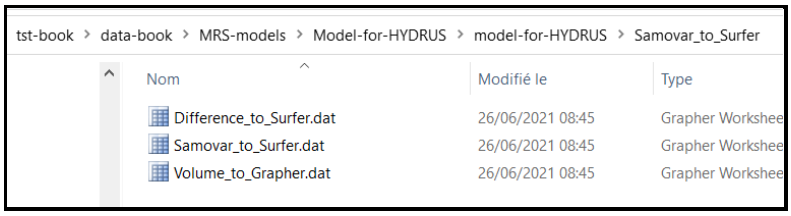

For observing the entire data set, we activate the ***3-D editor***. We reduce the depth interval for computing the water column thus getting a better resolution of the MRS water content estimate at shallow depth. And we reload MRS data (***Load***). The difference between the water contents along profile varies between -0.18 and 0.23 and the mean-square difference computed considering the entire data set is 0.07.



We get this result using the default parameters for MRS inversion. The difference can be reduced by selecting another equivalent MRS inverse model. We can also change the water flow model for better adjusting MRS measurements. Thus, the uncertainty in the modeling results is defined by the equivalence problem for both MRS and water flow modeling.

The computed water contents are automatically stored in the hard disk. These files can be visualized using the Surfer and Grapher programs.

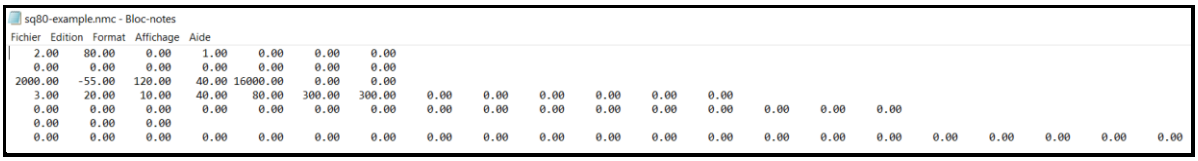


# Chapter 6. SAMOVAR 6x7: file formats

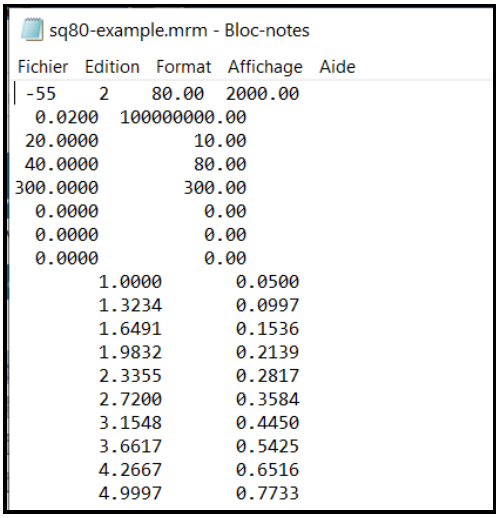
## *"name.nmc"*: parameters for computing the linear filter (the matrix)

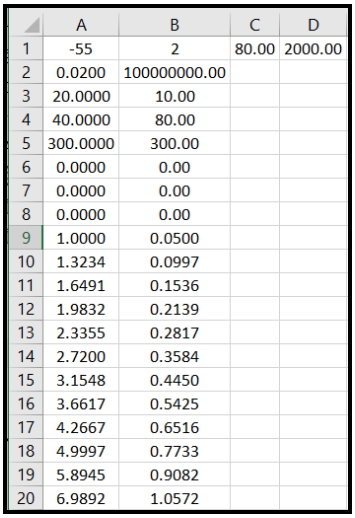
This file contains parameters for computing the linear filter (the matrix). This can be red with ***SAMOVAR 6x7 computing*** program.




## *"name.mrm"*: the linear filter (the matrix)

This file contains coefficients for computing the linear filter. This can be red with ***SAMOVAR 6x7 inversion*** and ***SAMOVAR 6x7 forward modeling*** programs.



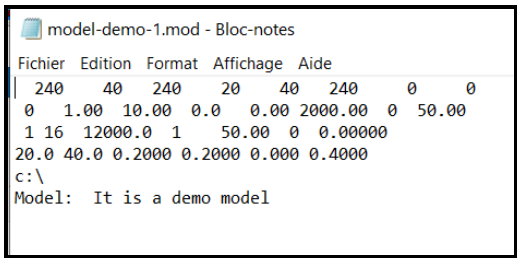



| | A | B | C | D |
|---|---|---|---|---|
| 1 | -55 | 2 | 80.00 | 2000.00 |
| 2 | 0.0200 | 100000000.00 | | |
| 3 | 20.0000 | 10.00 | | |
| 4 | 40.0000 | 80.00 | | |
| 5 | 300.0000 | 300.00 | | |
| 6 | 0.0000 | 0.00 | | |
| 7 | 0.0000 | 0.00 | | |
| 8 | 0.0000 | 0.00 | | |
| 9 | 1.0000 | 0.0500 | | |
| 10 | 1.3234 | 0.0997 | | |
| 11 | 1.6491 | 0.1536 | | |
| 12 | 1.9832 | 0.2139 | | |
| 13 | 2.3355 | 0.2817 | | |
| 14 | 2.7200 | 0.3584 | | |
| 15 | 3.1548 | 0.4450 | | |
| 16 | 3.6617 | 0.5425 | | |
| 17 | 4.2667 | 0.6516 | | |
| 18 | 4.9997 | 0.7733 | | |
| 19 | 5.8945 | 0.9082 | | |
| 20 | 6.9892 | 1.0572 | | |

A1 – the inclination of the geomagnetic field (degr.); B1 – loop type; C1 – Loop size (m); D1 – the Larmor frequency (Hz).
***Lines 2 - 8***: A – depth (m); B- resistivity (Ω.m).
***Lines 9 - 108***: coefficients for computing the linear filter.

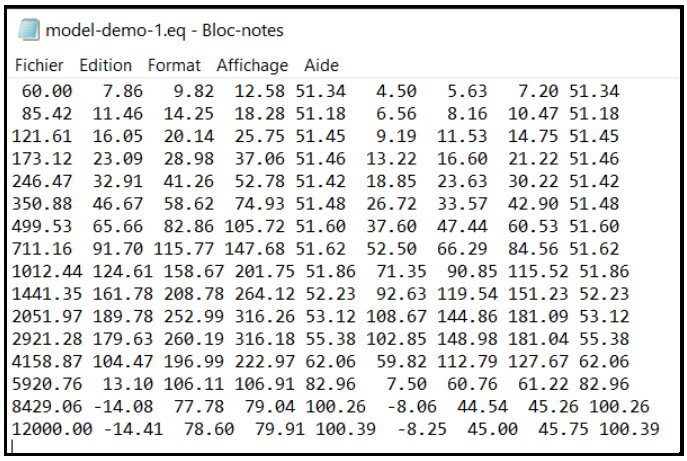
## *"name.mod"*: MRS forward modeling parameters

This file contains parameters of the MRS forward model and can be red with ***SAMOVAR 6x7 forward modeling*** program.



## "*name.eq*": synthetic MRS signal

The amplitude of the MRS signal in this file is computed considering the relaxation with the time constant $T_2^*$ and the dead time of 40 ms.




The table comments these data.

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 60.00 | 7.86 | 9.82 | 12.58 | 51.34 | 4.50 | 5.63 | 7.20 | 51.34 |
| 2 | 85.42 | 11.46 | 14.25 | 18.28 | 51.18 | 6.56 | 8.16 | 10.47 | 51.18 |
| 3 | 121.61 | 16.05 | 20.14 | 25.75 | 51.45 | 9.19 | 11.53 | 14.75 | 51.45 |
| 4 | 173.12 | 23.09 | 28.98 | 37.06 | 51.46 | 13.22 | 16.60 | 21.22 | 51.46 |
| 5 | 246.47 | 32.91 | 41.26 | 52.78 | 51.42 | 18.85 | 23.63 | 30.22 | 51.42 |
| 6 | 350.88 | 46.67 | 58.62 | 74.93 | 51.48 | 26.72 | 33.57 | 42.90 | 51.48 |
| 7 | 499.53 | 65.66 | 82.86 | 105.72 | 51.60 | 37.60 | 47.44 | 60.53 | 51.60 |
| 8 | 711.16 | 91.70 | 115.77 | 147.68 | 51.62 | 52.50 | 66.29 | 84.56 | 51.62 |
| 9 | 1012.44 | 124.61 | 158.67 | 201.75 | 51.86 | 71.35 | 90.85 | 115.52 | 51.86 |
| 10 | 1441.35 | 161.78 | 208.78 | 264.12 | 52.23 | 92.63 | 119.54 | 151.23 | 52.23 |
| 11 | 2051.97 | 189.78 | 252.99 | 316.26 | 53.12 | 108.67 | 144.86 | 181.09 | 53.12 |
| 12 | 2921.28 | 179.63 | 260.19 | 316.18 | 55.38 | 102.85 | 148.98 | 181.04 | 55.38 |
| 13 | 4158.87 | 104.47 | 196.99 | 222.97 | 62.06 | 59.82 | 112.79 | 127.67 | 62.06 |
| 14 | 5920.76 | 13.10 | 106.11 | 106.91 | 82.96 | 7.50 | 60.76 | 61.22 | 82.96 |
| 15 | 8429.06 | -14.08 | 77.78 | 79.04 | 100.26 | -8.06 | 44.54 | 45.26 | 100.26 |
| 16 | 12000.00 | -14.41 | 78.60 | 79.91 | 100.39 | -8.25 | 45.00 | 45.75 | 100.39 |

***Lines 1-16***: A – the pulse moment (A-ms); B – real amplitude of the FID1 signal (nV); C – imaginary amplitude of the FID1 signal (nV); D – amplitude of the FID1 signal (nV); E - phase of the FID1 signal (degr.); F – real amplitude of the FID2 signal (nV); G – imaginary amplitude of the FID2 signal (nV); H – amplitude of the FID2 signal (nV); I - phase of the FID2 signal (degr.).

## "*name.inp*": data summary file

"*name .inp*" file is generated by the data acquisition program or by a forward modeling program. This file is generated by the MRS forward modeling program (SAMOVAR 6x7).

model-demo-1.inp - Bloc-notes

Fichier Edition Format Affichage Aide

```
Model:  It is a demo model
Loop:  2 - 80.0 x N  Date: 24.06.2021;    Time: 17:39
 N    q        e    t2   noise  Udc   freq    phase
      2   16   9000.0
      0    0    0    0    0   0.00    0
 1     59  12.58     0    0.0     0 2000.00    51
 2     85  18.28     0    0.0     0 2000.00    51
 3    121  25.75     0    0.0     0 2000.00    51
 4    173  37.06     0    0.0     0 2000.00    51
 5    246  52.78     0    0.0     0 2000.00    51
 6    350  74.93     0    0.0     0 2000.00    51
 7    499 105.72     0    0.0     0 2000.00    51
 8    711 147.68     0    0.0     0 2000.00    51
 9   1012 201.75     0    0.0     0 2000.00    51
10   1441 264.12     0    0.0     0 2000.00    52
11   2051 316.26     0    0.0     0 2000.00    53
12   2921 316.18     0    0.0     0 2000.00    55
13   4158 222.97     0    0.0     0 2000.00    62
14   5920 106.91     0    0.0     0 2000.00    82
15   8429  79.04     0    0.0     0 2000.00   100
16  11999  79.91     0    0.0     0 2000.00   100
```

***Line 3:*** N = number of q value; q – first pulse parameter; e – FID1 amplitude; T2 – FID1 relaxation time T2*; mean ambient noise; Udc – DC/DC voltage; freq – FID1 signal frequency; phase – FID1 signal phase.

***Line 4:*** 2 – antenna type; 16 number of Q values; 9000 – amplification factor.

Since ***Line 5*** – MRS data.

### *"name.00", "name.01", "name.02", … , "name.0N"*: raw-data time series

Each file contains time-records corresponding to one value of pulse moment after stacking.

model-demo-1.01 - Bloc-notes

Fichier Edition Format Affichage Aide

```
2000.00      0      0      2      0      0      0.00      0.00    120
  120   112    20   320   120   160    20   320   120      0      0
  0.00    27.79   -49.77    43.69     0.00     0.71    36.69    43.69     0.00   -45.64   -40.50     0.00     0.00
  2.00   -36.50   -40.32    43.69     0.00     9.88    42.04    43.69     0.00   -33.53    42.51     0.00     0.00
  4.00   -30.46     3.89    43.69     0.00    25.81    18.18    43.69     0.00   -14.25     7.57     0.00     0.00
  6.00    11.16   -44.24    43.69     0.00   -28.23    52.52    43.69     0.00   -14.86     0.73     0.00     0.00
  8.00    28.47    37.74    43.69     0.00   -30.94    11.62    43.69     0.00   -19.96    -4.40     0.00     0.00
 10.00    21.05    47.81    43.69     0.00   -21.74    31.33    43.69     0.00   -48.99    -6.56     0.00     0.00
 12.00   -17.50   -49.68    43.69     0.00     3.08    42.53    43.69     0.00   -28.42   -28.23     0.00     0.00
 14.00    11.51   -33.55    43.69     0.00    19.95   -15.23    43.69     0.00    31.49    31.71     0.00     0.00
 16.00   -15.17   -33.35    43.69     0.00     1.88     0.96    43.69     0.00     1.42    -3.74     0.00     0.00
 18.00    25.10    -2.14    43.69     0.00   -25.49     9.29    43.69     0.00    22.09   -23.57     0.00     0.00
 20.00   -42.19    10.24    43.69     0.00   -13.72    49.43    43.69     0.00   -10.70    38.32     0.00     0.00
 22.00   -18.98    25.44    43.69     0.00    36.29     8.70    43.69     0.00    -9.70    42.83     0.00     0.00
 24.00   -34.89   -37.17    43.69     0.00    49.81    29.40    43.69     0.00   -46.83    -6.55     0.00     0.00
 26.00   -48.40   -43.76    43.69     0.00    19.78   -22.76    43.69     0.00    18.68   -39.57     0.00     0.00
 28.00   -47.12    -9.74    43.69     0.00     2.39   -32.28    43.69     0.00    18.32   -36.30     0.00     0.00
 30.00   -40.37    21.33    43.69     0.00   -39.24   -14.93    43.69     0.00    -4.47   -20.98     0.00     0.00
 32.00   -22.79    26.28    43.69     0.00   -29.80    20.04    43.69     0.00    14.80    18.24     0.00     0.00
```

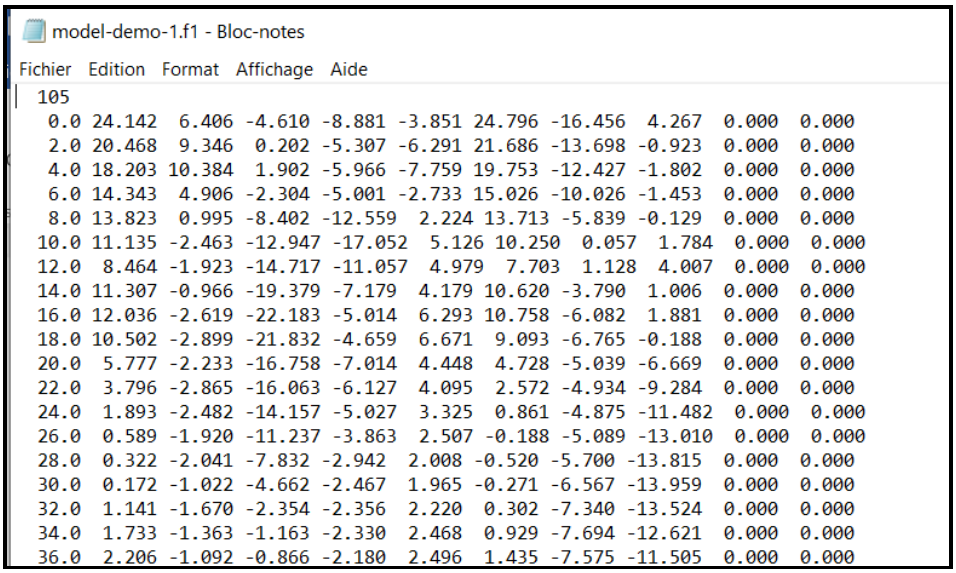
***Line 1***: clock frequency (Hz); the current pulse phase shift (degr); the amplifier phase shift (degr); antenna type; mean ambient noise (nV); Udc/dc (V); amplification factor; Tx impedance (Ω); number of readings.

***Line 2***: parameters of the measuring sequence.

Since ***Line 3***: time (ms); noise channel X (nV); noise channel Y (nV); the first pulse channel X; the first pulse channel Y; signal FID1 channel X (nV); signal FID1 channel Y (nV); the second pulse channel X; the second pulse channel Y; signal FID2 channel X (nV); signal FID2 channel Y (nV); signal SE channel X (nV); signal SE channel Y (nV).

### *"name.f0", "name.f1", "name.f2", … , "name.fN""*: filtered time series

Each file contains filtered time-records corresponding to one value of pulse moment.



model-demo-1.f1 - Bloc-notes

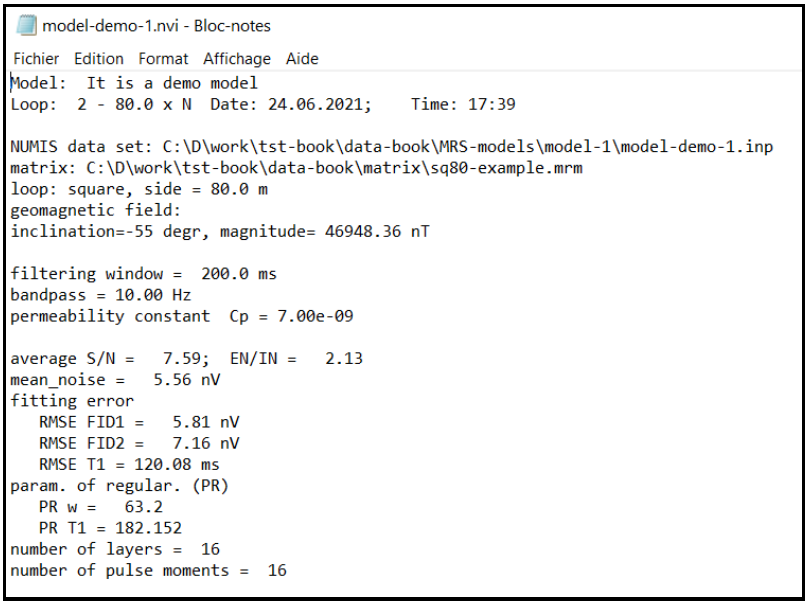
Fichier Edition Format Affichage Aide

```
 105
  0.0 24.142  6.406 -4.610 -8.881 -3.851 24.796 -16.456  4.267  0.000  0.000
  2.0 20.468  9.346  0.202 -5.307 -6.291 21.686 -13.698 -0.923  0.000  0.000
  4.0 18.203 10.384  1.902 -5.966 -7.759 19.753 -12.427 -1.802  0.000  0.000
  6.0 14.343  4.906 -2.304 -5.001 -2.733 15.026 -10.026 -1.453  0.000  0.000
  8.0 13.823  0.995 -8.402 -12.559  2.224 13.713 -5.839 -0.129  0.000  0.000
 10.0 11.135 -2.463 -12.947 -17.052  5.126 10.250  0.057  1.784  0.000  0.000
 12.0  8.464 -1.923 -14.717 -11.057  4.979  7.703  1.128  4.007  0.000  0.000
 14.0 11.307 -0.966 -19.379 -7.179  4.179 10.620 -3.790  1.006  0.000  0.000
 16.0 12.036 -2.619 -22.183 -5.014  6.293 10.758 -6.082  1.881  0.000  0.000
 18.0 10.502 -2.899 -21.832 -4.659  6.671  9.093 -6.765 -0.188  0.000  0.000
 20.0  5.777 -2.233 -16.758 -7.014  4.448  4.728 -5.039 -6.669  0.000  0.000
 22.0  3.796 -2.865 -16.063 -6.127  4.095  2.572 -4.934 -9.284  0.000  0.000
 24.0  1.893 -2.482 -14.157 -5.027  3.325  0.861 -4.875 -11.482  0.000  0.000
 26.0  0.589 -1.920 -11.237 -3.863  2.507 -0.188 -5.089 -13.010  0.000  0.000
 28.0  0.322 -2.041 -7.832 -2.942  2.008 -0.520 -5.700 -13.815  0.000  0.000
 30.0  0.172 -1.022 -4.662 -2.467  1.965 -0.271 -6.567 -13.959  0.000  0.000
 32.0  1.141 -1.670 -2.354 -2.356  2.220  0.302 -7.340 -13.524  0.000  0.000
 34.0  1.733 -1.363 -1.163 -2.330  2.468  0.929 -7.694 -12.621  0.000  0.000
 36.0  2.206 -1.092 -0.866 -2.180  2.496  1.435 -7.575 -11.505  0.000  0.000
```

***Line 1***: number of readings.

Since ***Line 2***: time (ms); signal FID1 amplitude (nV); signal FID1 noise (nV); noise channel X (nV); noise channel Y (nV); signal FID1 channel X (nV); signal FID1 channel Y (nV); signal FID2 channel X (nV); signal FID2 channel Y (nV); signal SE channel X (nV); signal SE channel Y (nV).

## "name.nvi": inversion summary file



model-demo-1.nvi - Bloc-notes

Fichier Edition Format Affichage Aide

```
Model:  It is a demo model
Loop:  2 - 80.0 x N  Date: 24.06.2021;    Time: 17:39

NUMIS data set: C:\D\work\tst-book\data-book\MRS-models\model-1\model-demo-1.inp
matrix: C:\D\work\tst-book\data-book\matrix\sq80-example.mrm
loop: square, side = 80.0 m
geomagnetic field:
inclination=-55 degr, magnitude= 46948.36 nT

filtering window =  200.0 ms
bandpass = 10.00 Hz
permeability constant  Cp = 7.00e-09

average S/N =   7.59;  EN/IN =   2.13
mean_noise =   5.56 nV
fitting error
   RMSE FID1 =   5.81 nV
   RMSE FID2 =   7.16 nV
   RMSE T1 = 120.08 ms
param. of regular. (PR)
   PR w =   63.2
   PR T1 = 182.152
number of layers =  16
number of pulse moments =  16
```

## "name.nov": inversion results

model-demo-1.nov - Bloc-notes

Fichier Edition Format Affichage Aide

```
 120  112   20  320  120  160   20  320  120    0    0
  16   16 -55 2000.0    2  80.0
0.0 1.0 0.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
1.0 2.0 1.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
2.0 3.0 2.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
3.0 4.0 3.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
4.0 5.0 4.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
5.0 6.0 5.5 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
6.0 8.2 7.1 0.7508  209.9 0.9076   376.4 9.002296e-06 1.900420e-05
8.2 11.0 9.6 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
11.0 14.8 12.9 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
14.8 20.0 17.4 0.3286  210.2 0.3971   377.1 3.952239e-06 2.050509e-05
20.0 27.0 23.5 15.9342  188.3 19.6830   392.6 2.123239e-04 1.486591e-03
27.0 36.5 31.8 18.7965  206.8 22.7857   367.5 2.154112e-04 2.035331e-03
36.5 49.2 42.9 1.4290  214.7 1.7202   377.1 1.712394e-05 2.183457e-04
49.2 66.4 57.8 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
66.4 89.7 78.1 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
89.7 120.0 104.8 0.0000    0.0 0.0000     0.0 0.000000e+00 0.000000e+00
59.999 12.026 13.355 279.490 2001.5 126.588   10.5  10.60   1.01    0.0   60.0 10.134 183.80 13.355  7.580  395.7  8.479 12.026 10.134
85.419 20.831 19.132 474.287 1999.3  2.056   16.2  18.81   1.16    0.0   85.4  9.806 534.39 19.132 10.861  395.6 11.915 20.831  9.806
121.605 18.018 27.279 1000.000 1999.7 32.323    7.7  18.93   2.45    0.0  121.6 15.711 165.42 27.279 15.495  395.6 15.968 18.018 15.711
173.131 41.449 38.862 135.882 2000.2 67.913   11.4  23.05   2.02    0.0  173.1 18.681 567.51 38.862 22.097  395.5 16.134 41.449 18.681
246.465 48.168 55.153 164.104 1999.6 34.831   12.7  29.74   2.35    0.0  246.5 40.023 191.30 55.153 31.415  395.4 18.199 48.168 40.023
350.876 81.516 77.902 183.080 2000.4 76.226   12.5  51.03   4.07    0.0  350.9 38.181 538.11 77.902 44.519  395.3 30.101 81.516 38.181
499.535 117.141 109.040 154.068 2000.1 62.288   10.5  66.38   6.31    0.0  499.5 59.612 478.14 109.040 62.678  395.1 40.683 117.141 59.612
711.159 149.928 150.487 165.571 1999.9 45.845    8.8  88.14  10.04    0.0  711.2 86.450 395.60 150.487 87.264  394.7 58.024 149.928 86.450
1012.432 198.328 202.405 189.321 2000.0 51.422   10.6 123.69  11.66    0.0 1012.4 109.348 424.20 202.405 118.474  393.9 71.948 198.328 109.348
1441.351 258.847 261.736 184.617 2000.1 54.541   11.6 159.35  13.71    0.0 1441.4 162.371 344.50 261.736 153.374  392.2 93.769 258.847 162.371
2051.971 313.938 311.151 202.688 2000.0 51.811    8.2 200.98  24.60    0.0 2052.0 170.610 433.64 311.151 180.116  388.9 112.235 313.938 170.610
2921.279 312.082 305.324 191.677 2000.1 58.816    8.0 195.32  24.44    0.0 2921.3 190.487 360.72 305.324 174.958  382.5 112.456 312.082 190.487
4158.874 214.424 209.785 227.534 2000.1 65.611    9.3 143.71  15.44    0.0 4158.9 131.657 357.17 209.785 124.209  374.4 81.845 214.424 131.657
5920.751 98.801 107.610 300.596 1999.9 78.863   12.3  72.93   5.91    0.0 5920.8 59.086 373.06 107.610 68.416  378.4 37.339 98.801 59.086
8429.067 77.682 79.249 196.732 1999.8 88.166    8.5  49.62   5.84    0.0 8429.1 42.786 424.87 79.249 48.974  390.0 29.381 77.682 42.786
11999.995 70.915 82.544 198.631 2000.1 100.305   12.0  45.58   3.79    0.0 12000.0 48.574 294.36 82.544 48.588  382.8 24.824 70.915 48.574
```

It is convenient to describe these data cut into a two tables:

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 120 | 112 | 20 | 320 | 120 | 160 | 20 | 320 | 120 | 0 | 0 | | | | | | | |
| 2 | 16 | 16 | -55 | 2000.0 | 2 | 80.0 | | | | | | | | | | | | | |
| 3 | 0.0 | 1.0 | 0.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 4 | 1.0 | 2.0 | 1.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 5 | 2.0 | 3.0 | 2.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 6 | 3.0 | 4.0 | 3.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 7 | 4.0 | 5.0 | 4.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 8 | 5.0 | 6.0 | 5.5 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 9 | 6.0 | 8.2 | 7.1 | 0.7508 | 209.9 | 0.9076 | 376.4 | 9.002296e-06 | 1.900420e-05 | | | | | | | | | | |
| 10 | 8.2 | 11.0 | 9.6 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 11 | 11.0 | 14.8 | 12.9 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 12 | 14.8 | 20.0 | 17.4 | 0.3286 | 210.2 | 0.3971 | 377.1 | 3.952239e-06 | 2.050509e-05 | | | | | | | | | | |
| 13 | 20.0 | 27.0 | 23.5 | 15.9342 | 188.3 | 19.6830 | 392.6 | 2.123239e-04 | 1.486591e-03 | | | | | | | | | | |
| 14 | 27.0 | 36.5 | 31.8 | 18.7965 | 206.8 | 22.7857 | 367.5 | 2.154112e-04 | 2.035331e-03 | | | | | | | | | | |
| 15 | 36.5 | 49.2 | 42.9 | 1.4290 | 214.7 | 1.7202 | 377.1 | 1.712394e-05 | 2.183457e-04 | | | | | | | | | | |
| 16 | 49.2 | 66.4 | 57.8 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 17 | 66.4 | 89.7 | 78.1 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |
| 18 | 89.7 | 120.0 | 104.8 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000000e+00 | 0.000000e+00 | | | | | | | | | | |

***Line 1***: parameters of the measuring sequence.
***Line 2***: A - number of layers in the inverse model; B – number of pulse moments; C - inclination of the geomagnetic field (degr.); D – the Larmor frequency; E – loop type; F – loop size.
***Lines 3 - 18***: A - depth from (m); B – depth to (m); C – depth layer-center (m); D – water content non-extrapolated (%); E – T2* (ms); F – water content extrapolated (%); G – T1 (ms); H - permeability (hydraulic conductivity) (m/s) of the corresponding layer; I – transmissivity ($m^2/s$) of the corresponding layer.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 59.999 | 12.026 | 13.355 | 279.490 | 2001.5 | 126.588 | 10.5 | 10.60 | 1.01 | 0.0 | 60.0 | 10.134 | 183.80 | 13.355 | 7.580 | 395.7 | 8.479 | 12.026 | 10.134 |
| 20 | 85.419 | 20.831 | 19.132 | 474.287 | 1999.3 | 2.056 | 16.2 | 18.81 | 1.16 | 0.0 | 85.4 | 9.806 | 534.39 | 19.132 | 10.861 | 395.6 | 11.915 | 20.831 | 9.806 |
| 21 | 121.605 | 18.018 | 27.279 | 1000.000 | 1999.7 | 32.323 | 7.7 | 18.93 | 2.45 | 0.0 | 121.6 | 15.711 | 165.42 | 27.279 | 15.495 | 395.6 | 15.968 | 18.018 | 15.711 |
| 22 | 173.131 | 41.449 | 38.862 | 135.882 | 2000.2 | 67.913 | 11.4 | 23.05 | 2.02 | 0.0 | 173.1 | 18.681 | 567.51 | 38.862 | 22.097 | 395.5 | 16.134 | 41.449 | 18.681 |
| 23 | 246.465 | 48.168 | 55.153 | 164.104 | 1999.6 | 34.831 | 12.7 | 29.74 | 2.35 | 0.0 | 246.5 | 40.023 | 191.30 | 55.153 | 31.415 | 395.4 | 18.199 | 48.168 | 40.023 |
| 24 | 350.876 | 81.516 | 77.902 | 183.080 | 2000.4 | 76.226 | 12.5 | 51.03 | 4.07 | 0.0 | 350.9 | 38.181 | 538.11 | 77.902 | 44.519 | 395.3 | 30.101 | 81.516 | 38.181 |
| 25 | 499.535 | 117.141 | 109.040 | 154.068 | 2000.1 | 62.288 | 10.5 | 66.38 | 6.31 | 0.0 | 499.5 | 59.612 | 478.14 | 109.040 | 62.678 | 395.1 | 40.683 | 117.141 | 59.612 |
| 26 | 711.159 | 149.928 | 150.487 | 165.571 | 1999.9 | 45.845 | 8.8 | 88.14 | 10.04 | 0.0 | 711.2 | 86.450 | 395.60 | 150.487 | 87.264 | 394.7 | 58.024 | 149.928 | 86.450 |
| 27 | 1012.432 | 198.328 | 202.405 | 189.321 | 2000.0 | 51.422 | 10.6 | 123.69 | 11.66 | 0.0 | 1012.4 | 109.348 | 424.20 | 202.405 | 118.474 | 393.9 | 71.948 | 198.328 | 109.348 |
| 28 | 1441.351 | 258.847 | 261.736 | 184.617 | 2000.1 | 54.541 | 11.6 | 159.35 | 13.71 | 0.0 | 1441.4 | 162.371 | 344.50 | 261.736 | 153.374 | 392.2 | 93.769 | 258.847 | 162.371 |
| 29 | 2051.971 | 313.938 | 311.151 | 202.688 | 2000.0 | 51.811 | 8.2 | 200.98 | 24.60 | 0.0 | 2052.0 | 170.610 | 433.64 | 311.151 | 180.116 | 388.9 | 112.235 | 313.938 | 170.610 |
| 30 | 2921.279 | 312.082 | 305.324 | 191.677 | 2000.1 | 58.816 | 8.0 | 195.32 | 24.44 | 0.0 | 2921.3 | 190.487 | 360.72 | 305.324 | 174.958 | 382.5 | 112.456 | 312.082 | 190.487 |
| 31 | 4158.874 | 214.424 | 209.785 | 227.534 | 2000.1 | 65.611 | 9.3 | 143.71 | 15.44 | 0.0 | 4158.9 | 131.657 | 357.17 | 209.785 | 124.209 | 374.4 | 81.845 | 214.424 | 131.657 |
| 32 | 5920.751 | 98.801 | 107.610 | 300.596 | 1999.9 | 78.863 | 12.3 | 72.93 | 5.91 | 0.0 | 5920.8 | 59.086 | 373.06 | 107.610 | 68.416 | 378.4 | 37.339 | 98.801 | 59.086 |
| 33 | 8429.067 | 77.682 | 79.249 | 196.732 | 1999.8 | 88.166 | 8.5 | 49.62 | 5.84 | 0.0 | 8429.1 | 42.786 | 424.87 | 79.249 | 48.974 | 390.0 | 29.381 | 77.682 | 42.786 |
| 34 | 11999.995 | 70.915 | 82.544 | 198.631 | 2000.1 | 100.305 | 12.0 | 45.58 | 3.79 | 0.0 | 12000.0 | 48.574 | 294.36 | 82.544 | 48.588 | 382.8 | 24.824 | 70.915 | 48.574 |

***Lines 19-34***: A – the first pulse moment (A-ms); B – measured FID1 amplitude (nV); C – FID1 reconstructed after inversion (nV); D – T2* (ms) for FID1; E – signal FID1 frequency (Hz); F – FID1 phase (degr.); G – mean noise after stacking (nV); H – signal FID1 mean amplitude (nV); I – FID1 signal to noise ratio; J – ambient noise (nV); K – the second pulse moment (A-ms); L – measured FID2 amplitude (nV) for T1 inversion; M – T1 (ms); N – FID1 reconstructed after inversion (nV); O – FID2 reconstructed after inversion (nV); P – T1 reconstructed after inversion (ms); Q – signal FID1 mean amplitude (nV); R – measured FID1 amplitude (nV); S – signal FID2 amplitude reconstructed after inversion (nV).

### *"name.nbl"*: the black list

This file contains parameters of the FID1 signal. Records corresponding to one pulse moment have a quality assignment: ***good*** – this record is used for the inversion; ***bad*** – this record is blacklisted and is excluded from the data set for inversion. The blacklist can be red with ***SAMOVAR 6x7 inversion*** program.

model-demo-1.nbl - Bloc-notes

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| qualite | record | q(A-ms) | E(nV) | T2(ms) | freq(Hz) | phase(degr) |
|---|---|---|---|---|---|---|
| good | 1 | 60.00 | 12.03 | 279.49 | 2001.55 | 126.59 |
| good | 2 | 85.42 | 20.83 | 474.29 | 1999.31 | 2.06 |
| good | 3 | 121.60 | 18.02 | 1000.00 | 1999.74 | 32.32 |
| good | 4 | 173.13 | 41.45 | 135.88 | 2000.24 | 67.91 |
| good | 5 | 246.46 | 48.17 | 164.10 | 1999.55 | 34.83 |
| good | 6 | 350.88 | 81.52 | 183.08 | 2000.45 | 76.23 |
| good | 7 | 499.53 | 117.14 | 154.07 | 2000.12 | 62.29 |
| good | 8 | 711.16 | 149.93 | 165.57 | 1999.93 | 45.84 |
| good | 9 | 1012.43 | 198.33 | 189.32 | 1999.98 | 51.42 |
| good | 10 | 1441.35 | 258.85 | 184.62 | 2000.05 | 54.54 |
| good | 11 | 2051.97 | 313.94 | 202.69 | 1999.97 | 51.81 |
| good | 12 | 2921.28 | 312.08 | 191.68 | 2000.05 | 58.82 |
| good | 13 | 4158.87 | 214.42 | 227.53 | 2000.07 | 65.61 |
| good | 14 | 5920.75 | 98.80 | 300.60 | 1999.91 | 78.86 |
| good | 15 | 8429.07 | 77.68 | 196.73 | 1999.85 | 88.17 |
| good | 16 | 12000.00 | 70.92 | 198.63 | 2000.07 | 100.30 |

### *"name.nid"*: records for inversion

This file contains the amplitudes of FID1 signal versus time used for inversion and corresponding to each pulse moment.

model-demo-1.nid - Bloc-notes

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| 100 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 320.7 | 636.4 | 952.0 | 1267.7 | 1583.4 | 1899.1 | 2214.8 | 2530.4 | 2846.1 | 3161.8 | 3477.5 | 3793.2 | 4108.9 | 4424.5 | 4740.2 | 5055.9 |
| 0.00 | 24 | 18 | 13 | 39 | 61 | 82 | 122 | 148 | 198 | 255 | 314 | 316 | 213 | 107 | 89 | 86 |
| 2.00 | 20 | 12 | 13 | 39 | 58 | 81 | 119 | 143 | 197 | 257 | 305 | 310 | 214 | 101 | 92 | 88 |
| 4.00 | 18 | 8 | 11 | 43 | 61 | 84 | 112 | 141 | 198 | 254 | 296 | 306 | 214 | 93 | 92 | 82 |
| 6.00 | 14 | 9 | 13 | 41 | 56 | 83 | 103 | 143 | 197 | 246 | 290 | 302 | 211 | 92 | 85 | 77 |
| 8.00 | 14 | 13 | 15 | 41 | 49 | 81 | 97 | 147 | 191 | 241 | 288 | 297 | 203 | 95 | 79 | 74 |
| 10.00 | 11 | 15 | 23 | 43 | 46 | 80 | 93 | 149 | 185 | 234 | 280 | 287 | 203 | 99 | 72 | 72 |
| 12.00 | 8 | 15 | 25 | 42 | 42 | 76 | 88 | 149 | 185 | 229 | 279 | 278 | 205 | 99 | 67 | 64 |
| 14.00 | 11 | 11 | 23 | 49 | 40 | 77 | 91 | 144 | 180 | 225 | 280 | 276 | 199 | 95 | 63 | 61 |
| 16.00 | 12 | 13 | 28 | 47 | 34 | 76 | 94 | 143 | 177 | 223 | 284 | 274 | 193 | 96 | 60 | 56 |
| 18.00 | 11 | 15 | 28 | 45 | 32 | 75 | 97 | 140 | 175 | 223 | 288 | 273 | 192 | 96 | 60 | 55 |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | | | | | | | | | | | | | | | | |
| 2 | 5.0 | 320.7 | 636.4 | 952.0 | 1267.7 | 1583.4 | 1899.1 | 2214.8 | 2530.4 | 2846.1 | 3161.8 | 3477.5 | 3793.2 | 4108.9 | 4424.5 | 4740.2 | 5055.9 |
| 3 | 0.00 | 24 | 18 | 13 | 39 | 61 | 82 | 122 | 148 | 198 | 255 | 314 | 316 | 213 | 107 | 89 | 86 |
| 4 | 2.00 | 20 | 12 | 13 | 39 | 58 | 81 | 119 | 143 | 197 | 257 | 305 | 310 | 214 | 101 | 92 | 88 |
| 5 | 4.00 | 18 | 8 | 11 | 43 | 61 | 84 | 112 | 141 | 198 | 254 | 296 | 306 | 214 | 93 | 92 | 82 |
| 6 | 6.00 | 14 | 9 | 13 | 41 | 56 | 83 | 103 | 143 | 197 | 246 | 290 | 302 | 211 | 92 | 85 | 77 |
| 7 | 8.00 | 14 | 13 | 15 | 41 | 49 | 81 | 97 | 147 | 191 | 241 | 288 | 297 | 203 | 95 | 79 | 74 |
| 8 | 10.00 | 11 | 15 | 23 | 43 | 46 | 80 | 93 | 149 | 185 | 234 | 280 | 287 | 203 | 99 | 72 | 72 |
| 9 | 12.00 | 8 | 15 | 25 | 42 | 42 | 76 | 88 | 149 | 185 | 229 | 279 | 278 | 205 | 99 | 67 | 64 |
| 10 | 14.00 | 11 | 11 | 23 | 49 | 40 | 77 | 91 | 144 | 180 | 225 | 280 | 276 | 199 | 95 | 63 | 61 |
| 11 | 16.00 | 12 | 13 | 28 | 47 | 34 | 76 | 94 | 143 | 177 | 223 | 284 | 274 | 193 | 96 | 60 | 56 |
| 12 | 18.00 | 11 | 15 | 28 | 45 | 32 | 75 | 97 | 140 | 175 | 223 | 288 | 273 | 192 | 96 | 60 | 55 |
| 13 | 20.00 | 6 | 17 | 20 | 43 | 34 | 76 | 99 | 136 | 175 | 227 | 291 | 275 | 196 | 96 | 66 | 60 |
| 14 | 22.00 | 4 | 18 | 19 | 40 | 32 | 74 | 98 | 133 | 172 | 225 | 290 | 273 | 193 | 95 | 65 | 59 |
| 15 | 24.00 | 2 | 18 | 19 | 38 | 31 | 73 | 99 | 129 | 169 | 222 | 288 | 271 | 192 | 95 | 65 | 57 |
| 16 | 26.00 | 1 | 19 | 18 | 36 | 32 | 72 | 99 | 126 | 167 | 220 | 286 | 270 | 191 | 95 | 66 | 56 |
| 17 | 28.00 | 0 | 19 | 17 | 34 | 33 | 70 | 99 | 123 | 166 | 219 | 283 | 270 | 191 | 95 | 67 | 55 |

A1 – number of the signal records.
***Line 2***: the amplitude shifts for graphical representation with SAMOVAR 6x7.
***Lines 3 - 102***: A – time (ms); from B to Q – amplitude of the FID1 signal (nV).

## *"name _TF.txt"*: parameters for the Tikhonov regularization

This file contains parameter for using with the Tikhonov regularization method. The "optimal" regularization is set automatically if the option "***auto***" is used. Otherwise this is the user defined value.

model-demo-1_TF.txt - Bloc-notes

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```
Water content regularization
Optimal solution for Par.Regul.=   63.246
Par.Regul. for T1 =  182.152
N   Par.Regul.    TF          RMSE(nV)  dw/dz norm L2  w norm L2
  0      0.000    0.080384      4.258      0.266701       0.259518
  1      2.000    0.080368      4.261      0.266549       0.259462
  2      5.657    0.080034      4.274      0.264487       0.258665
  3     10.392    0.079511      4.303      0.261058       0.257329
  4     16.000    0.079033      4.349      0.257503       0.255933
  5     22.361    0.078632      4.411      0.254009       0.254545
  6     29.394    0.078320      4.487      0.250680       0.253204
  7     37.041    0.078096      4.575      0.247563       0.251929
  8     45.255    0.077952      4.672      0.244673       0.250726
  9     54.000    0.077853      4.812      0.241069       0.249182
 10     63.246    0.077799      5.030      0.235930       0.246965
 11     72.966    0.077834      5.263      0.230904       0.244815
 12     83.138    0.077948      5.506      0.226014       0.242740
 13     93.744    0.078129      5.755      0.221280       0.240747
 14    104.766    0.078365      6.008      0.216712       0.238837
 15    116.190    0.078647      6.262      0.212327       0.237017
```

# Index

## T



## W