SCSINV
DOCUMENTATION

ZONGE Data Processing

Smooth-Model CSAMT Inversion

version 2.10

Scott MacInnes
Mykle Raymond
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Zonge Engineering and Research Organization, Inc.
3322 East Fort Lowell Road, Tucson, AZ 85716 USA
Tel:(520)327-5501 Fax:(520)325-1588 Email:zonge@zonge.com

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SCSINV

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Introduction

Smooth-model inversion is a robust method for converting CSAMT measurements to models of resistivity versus depth. Observed apparent resistivity and impedance phase data for each station are used to determine the parameters of a layered-earth model. Layer thicknesses are fixed before the inversion starts by calculating source-field penetration depths for each frequency. Layer resistivities are given a uniform starting value based on controlled-source apparent resistivities. Layer resistivities are adjusted iteratively during inversion until the calculated CSAMT response is as close as possible to observed data, consistent with smoothness constraints. Including smoothness constraints in the inversion limits resistivity variation from layer to layer and produces a model with smoothly varying resistivities.

SCSINV's forward-modeling algorithm can include the effects of finite transmitter-receiver separation and a three-dimensional source field. Source types include a vertically incident plane wave for natural source modeling and grounded electric bipole or horizontal loop sources for CSAMT modeling. Accurate impedance magnitude and phase values are calculated for all frequencies and transmitter-receiver separations. Impedances can be calculated for scalar, vector or tensor survey configurations.

Lateral variation is determined by inverting successive stations along a survey line to produce a grid of smooth-model resistivity. Resistivity values are placed at the midpoint of each layer, forming a column below every station. The columns form an array representing a cross-section of model resistivity. Results for a complete line can be presented in pseudosection form by contouring model resistivities.

Inverting apparent resistivity and impedance phase to smoothly varying model resistivities is an effective way to display the information inherent in CSAMT measurements. Smooth-model inversion does not require any a priori estimates of model parameters. The data are automatically transformed to resistivity as a function of depth. Models with smoothness constraints are complementary to more detailed models incorporating specific geologic information.

Installation

Minimum Hardware Configuration

The minimum hardware configuration needed to operate SCSINV is a PC running MS Windows 9?/ME/NT/2000 with screen graphics set to “true” or “high” color (16-bit) mode, 32 MB or more of RAM and at least 2 MB of free disk space.

Installation Procedure

Each distribution copy of SCSINV may be installed on more than one computer, but it comes with either a key-disk software registration system compatible with Windows 95/98 or a parallel port hardware-lock or “dongle” compatible with all MS Window versions except 3.?. Backup copies of installed files may be made freely, but they will function only with valid software registration.

Key-disk software registration can be moved from the distribution disk to a hard-drive for extensive use on one computer. Key-disk registration may later be moved back to the distribution disk for installation on another computer. Once SCSINV and hardware lock software is installed, dongles may be moved from one computer to another, but should only be removed or added with computer and printer power off.

Installing program and sample data files

A SETUP program is provided to install SCSINV programs to your hard drive. SETUP copies files to your hard drive and unzips them, but does not make any changes to operating system files.

To install SCSINV program files from a 3.5”disk, place the distribution disk in a floppy disk drive and log-on to that drive. Then type "SETUP" and press Enter. You will see a screen title showing the program’s name and version number. Below the title block a set of highlighted fields specify the source drive you are installing SCSINV from, usually floppy drive A: or B:, and the target hard drive letter and path in which SCSINV should be installed. It is usually easiest to put SCSINV programs in a directory that is already on your computer’s MS-DOS path. You can move from field to field in the SETUP program’s screen by pressing the Tab key to move forward and Shift+Tab to move backward. To cycle through disk drive letters, press the space bar or left and right arrow keys. Select drive letters and edit the target path to suit your computer’s configuration. When you press F10, SETUP will verify your edited changes and will extract files from #SCSINV.EXE to your target directory.

If you are installing programs from a CD, SETUP allows you to move groups of program files from the distribution CD to a target hard-drive directory. As with floppy-disk installation, it is usually easiest to put modeling programs from a CD into a single directory on your computer’s MS-DOS path (such as c:\datpro). Using a single directory reduces the length of the MS-DOS path string.

SETUP does not alter any of your computer’s system configuration files. After installation, SCSINV may be run from the command line, from the start menu or from a Windows desktop shortcut.

After installation, the subdirectory holding SCSINV should have the following files:

SCSINV program files:

SCSINV.EXE	- shell to build and review models.
RSCSINV.EXE	- smooth-model CSAMT inversion program.
SCSREG.EXE	- registration program.

Sample data files:

SCSDEMO.MDE	- survey annotation and configuration information.
SCSDEMO.AVG	- observed data and estimated measurement error.
SCSDEMO.STN	- station grid locations and elevations.
SCSDEMO.SCS	- inversion control and data RSCSINV input file.
SCSDEMO.M1D	- smooth-model resistivity model RSCSINV output file.
SCSDEMO.OBS	- smooth-model observed and calculated data RSCSINV output file.

Note that sample data files must be read/writeable. Test data files distributed from a CD-ROM may need their attributes modified from read only to read/write.

Moving key-disk software registration to your hard drive.

Key-disk software registration may be left on the distribution disk. RSCSINV will then run only when the distribution disk is present in your floppy-disk drive. For more convenience, you can move key-disk registration to your hard-drive. When this is done, the 3.5" key-disk will not be required to operate the program. However, if the hard disk is transferred to another person, reformatted or corrupted, that copy of the protection is lost. One spare copy of the software registration is included on each distribution disk.

IF your software was provided for demonstration purposes, then software registration may NOT be moved to a hard disk. Typically, the registration is set to expire 30 days after you first use the program. Registration may be reset by purchasing SCSINV and obtaining a reset code by fax or email.

The utility EVMOVE.COM is provided on the distribution key disk. Assuming that the 3.5" distribution disk is in drive A: and that your hard drive is labeled C:, type

"EVMOVE A: C:" to move a copy of software registration from drive A: to drive C:
"EVMOVE C: A:" to recall a copy of software registration from drive C: to drive A:

Installing a hardware lock

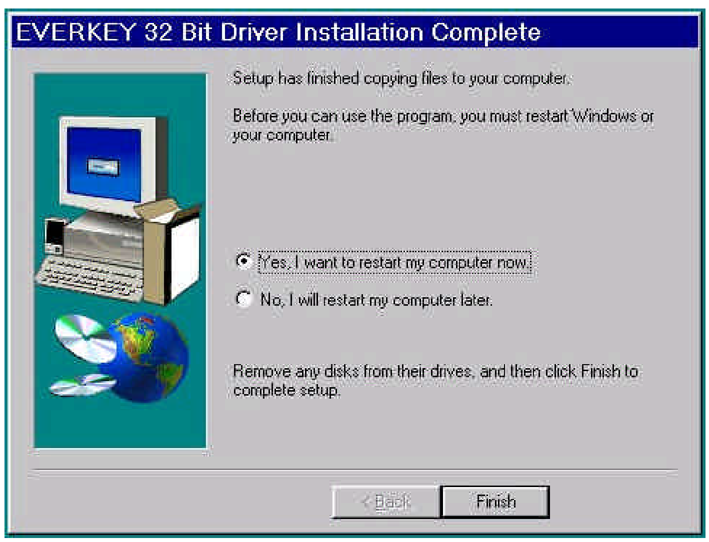
A parallel-port hardware lock or dongle is required for computers running Windows NT. Using SCSINV's hardware-lock registration system requires additional configuration steps. If your program comes with a parallel-port hardware lock, install it by turning off power to your computer and printer. Unplug the parallel-port printer cable from the back of your computer and plug the hardware lock into your computer's 25-pin parallel port. Then plug the parallel printer cable into the hardware lock, piggyback fashion.

You do not have to have a printer physically installed for the hardware lock to function. If you do have a printer connected, it must be turned on and on-line when you run SCSINV. If you have more than one parallel port, it makes no difference which one you use.

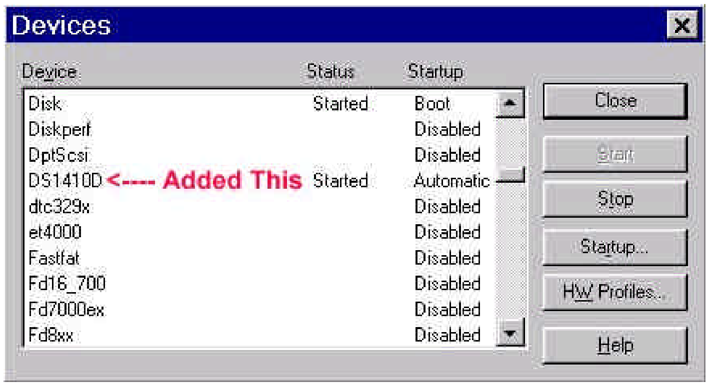
Note that you must ensure the end of the hardware lock labeled "Computer" is connected to your computer's parallel port. It is possible to plug the hardware lock in backwards, which may damage the hardware lock, the parallel port or both.

SETUP32

This file needs to be executed once to install a driver that allows the hardware-lock software to access the parallel port. The driver file is DS1410D.SYS, which is put into your computer's driver directory. After rebooting PCs running Windows NT or 2000, you will see this driver listed in the 'Devices'. (START / Settings / Control Panel / Devices). This driver is automatically started when your computer boots up.



Execute the program SETUP32, then reboot your PC. After re-booting a PC running Windows NT or 2000, the list of 'Devices' should include a new driver, DS1410D



Test the software registration by executing SCSREG from the SCSINV hard-disk directory. You should see text like:

Registered to: Alaska Earth Sciences Serial # 1099
Copyright 1999 Zonge Engineering
All Rights Reserved.

A software registration check is done every time RSCSINV is initiated. RSCSINV calls SCSREG to check for valid software registration. Key-disk systems make a software check, while hardware-lock systems look for an appropriate hardware key or “dongle” in the parallel port.

Graphics Configuration

SCSINV expects VGA, SVGA or XVGA graphics set to high color (16-bit) mode. Review Data plots may be plotted on your printer, exported to wmf files for pasting into MS-Word documents or exported to HPGL graphics files for later hardcopy plotting.

Program MODSECT (v4.20d or higher) and its associated files may be used to plot model sections. MODSECT shows model section plots on screen and can export plots to windows metafiles, write script and data files for Oasis Montage, or write script and data files for Surfer v6.0. MODSECT documentation details its hardcopy plot options.

Recall Procedure

To recall SCSINV back to the distribution disk, place the distribution disk in a drive and log on to that drive, then type “RECALL” and press the Enter key. RECALL displays a screen with fields for the drive and directory where SCSINV is installed and for the letter of the floppy drive holding the SCSINV distribution disk. Edit the source drive and path to match your computer’s configuration and then press F10 to start the RECALL procedure. RECALL erases SCSINV.EXE, RSCSINV.EXE, SCSREG.EXE and SCSDEMO.* from the “recall from” directory.

Program Use

Overview

SCSINV is a pair of programs for inverting CSAMT data into a smoothly varying model. SCSINV.EXE is a shell program providing utility functions for building and reviewing inversion models, while RSCSINV.EXE is the core inversion program. RSCSINV can either be run from within SCSINV, from the command line or from a batch file.

Information is exchanged between programs via ASCII text data files that may be externally edited if necessary for special projects. Both program look for file names on the command line. File-name extensions are used to flag the file type, i.e.. avg files end with the extension ".AVG" and station location files end with the extension ".STN". RSCSINV.EXE input files end with the extension ".SCS" and RSCSINV.EXE produces m1d and obs files. m1d files hold inverted model parameters and obs files hold observed and calculated CSAMT/NSAMT data.

Observed data are prepared for inversion using the shell program, SCSINV.EXE. SCSINV can read observed CSAMT data from Zonge format avg or z files. avg files are preferable because they include information about measurement error. Survey configuration information, such as transmitter bipole location, length and orientation, are read from mde files. Station location coordinates may be input from optional stn files. After collecting information from these diverse source files, SCSINV sorts the observed data and saves it in an scs file.

RSCSINV.EXE, the core inversion program, reads scs files, inverts observed data, and writes inverted results in a m1d file holding model resistivity versus station location and depth. RSCSINV saves both observed and calculated data in an obs file. The tabular format used in m1d and obs files is directly useable by most general purpose contouring programs. Zonge utility program MODSECT may be used to produce color filled model sections on-screen, exported to wmf or hpgl plot files, printed via the Windows print manager, plotted with Surfer or plotted with Oasis montaj.

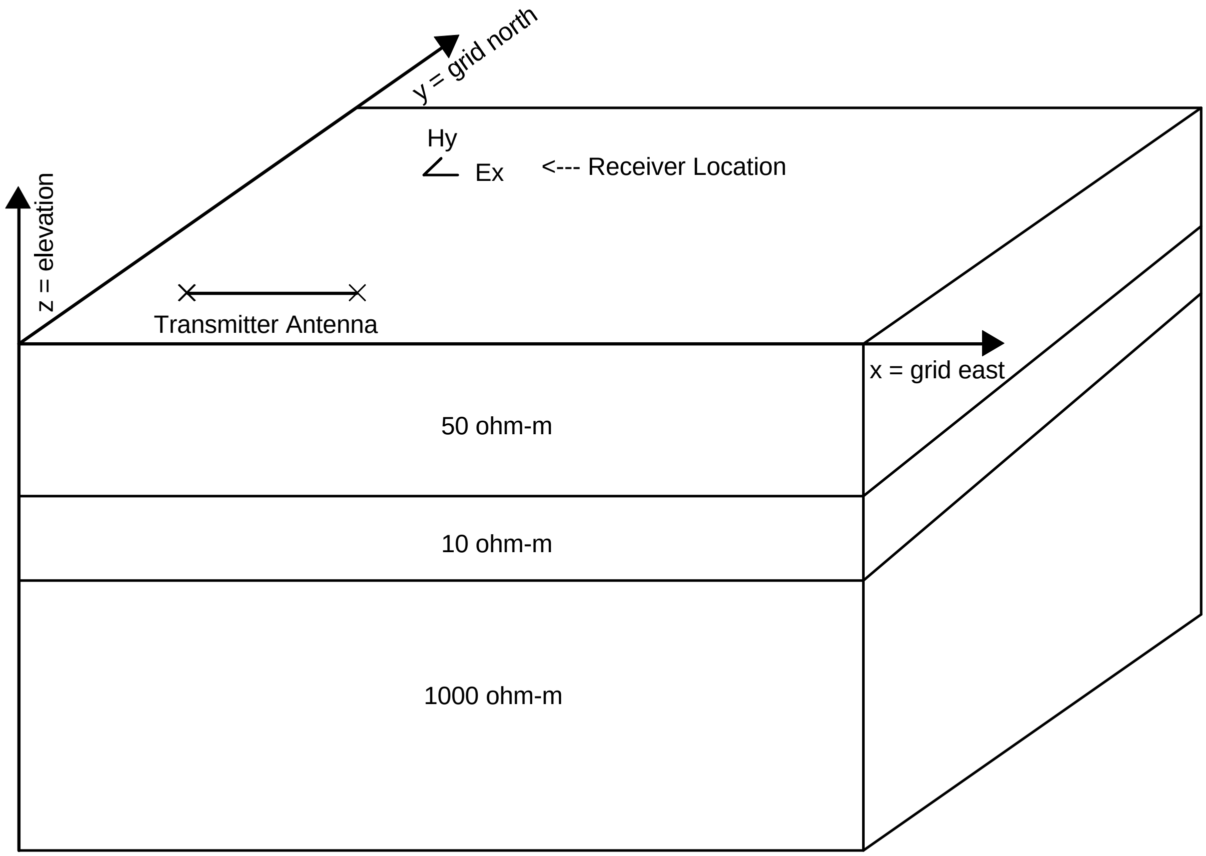
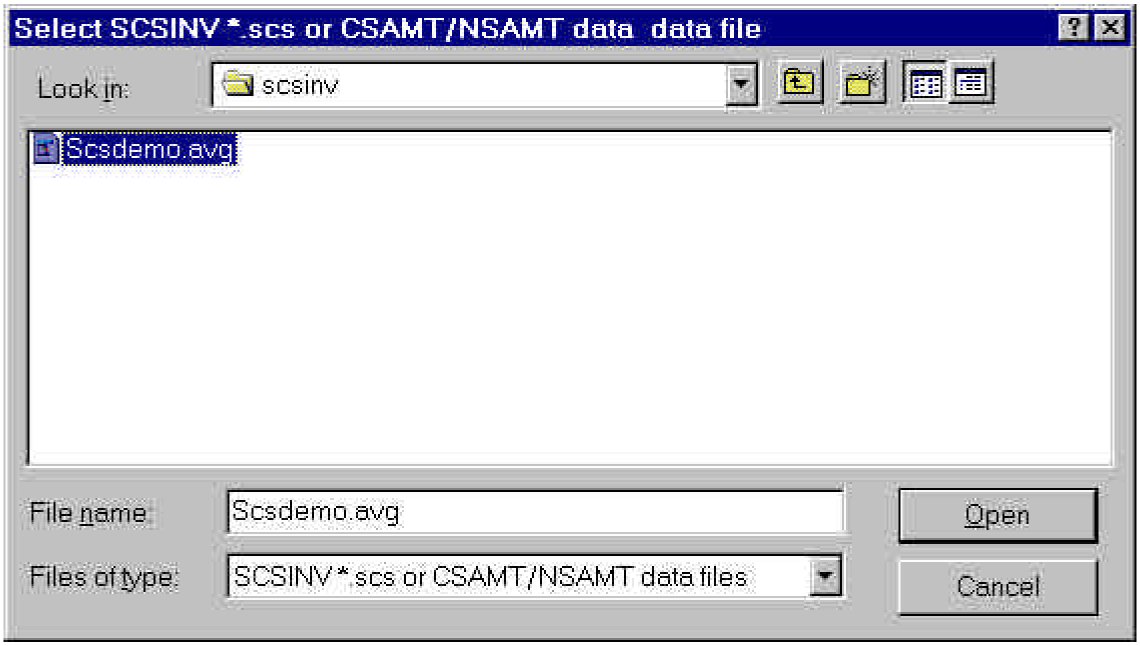


Figure 1: SCSINV uses a right-handed coordinate system. Positive x corresponds to grid east, positive y corresponds to grid north, and z corresponds to elevation. Distances are specified in meters or feet and azimuths are given in degrees clockwise from grid north. Observed data are apparent resistivity and impedance phase measured at a number of frequencies. Data are usually grouped by line, one line per file. SCSINV can model scalar data using one transmitter and two perpendicular components of E and H, vector data using one transmitter and four components of E and H or tensor data using two transmitters and four components of E and H. Source types include plane wave, grounded electric bipole or horizontal loop.

Typical SCSINV Modeling Sequence

Start SCSINV by type "SCSINV " on the command line, by running SCSINV.EXE from the Start menu or with a Windows shortcut. SCSINV will create a dialog box showing all files with .scs, .avg or .z extensions. Selecting a scs file will open an existing SCSINV model. Selecting an avg or z file holding CSAMT or NSAMT data will put SCSINV to building a new model file.



Choosing the sample file scsdemo.avg and clicking on the OK button indicates that you are ready to build a SCSINV input file. SCSINV first reads survey annotation and configuration information from an optional mde file. Sample file scsdemo.mde includes information about length units (keyword Units), GDP to client station number scaling, transmitter length (TxLen), Tx orientation (TxBrg) and Tx center location (TxCX and TxCY). All lengths and distances should be in the length units specified by the mde-file keyword Units. If no mde file is available, SCSINV uses default values, which you will have a chance to correct in the survey configuration dialog box.

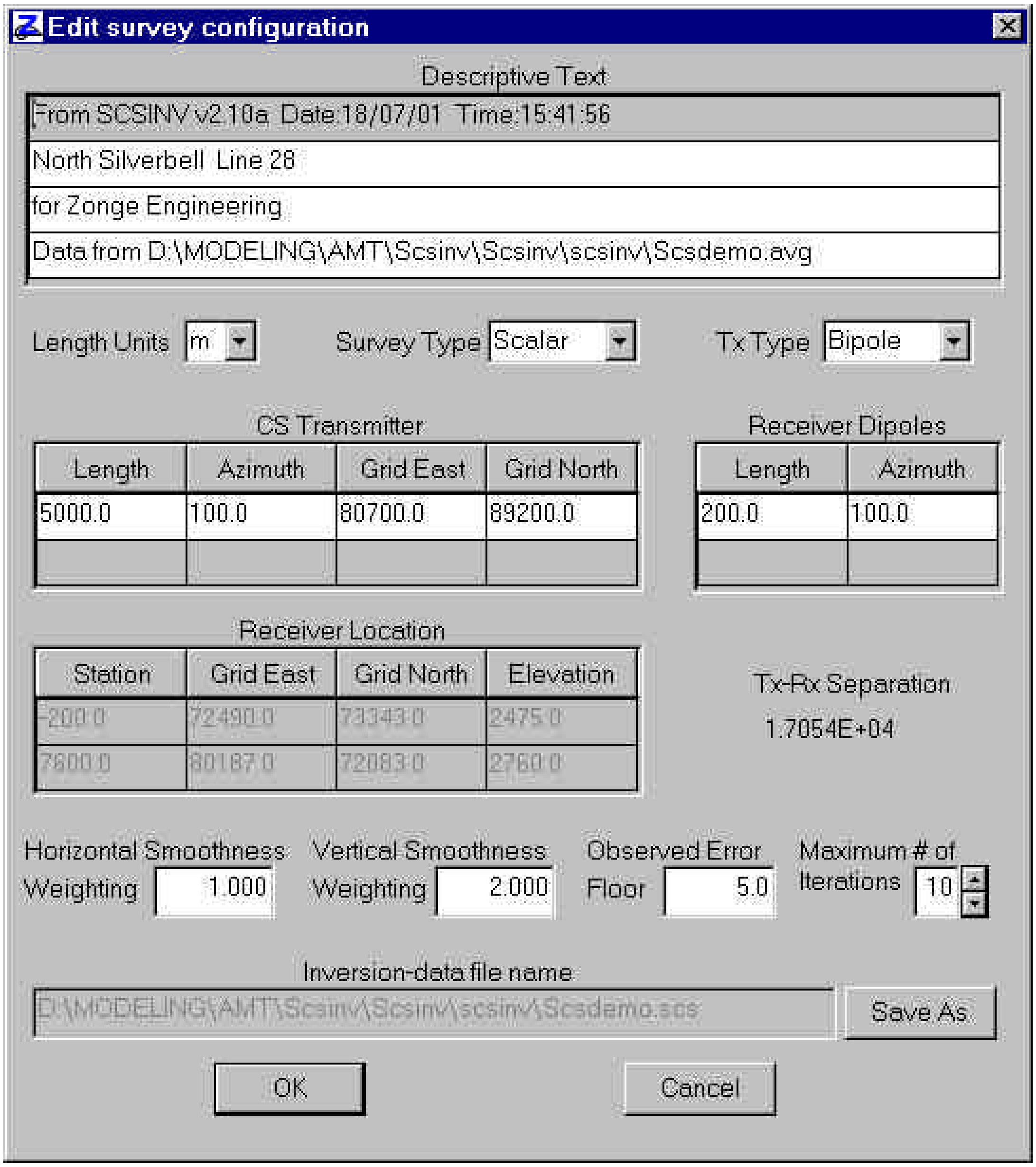
A mechanism for linear shifting and scaling of station numbers is provided in mde files using keywords StnBeg, StnDelt, LblFrst and LblDel. StnBeg and StnDelt specify the first GDP station number and increment. GDP station numbers are used in avg and z files. LblFrst and LblDelt define the first client station number and increment. Client station numbers are used on plots, in stn files and in all modeling program files.

SCSINV reads CSAMT or NSAMT data from Zonge format .avg or .z files. Scsdemo.avg includes GDP station number, frequency, apparent resistivity, impedance phase, resistivity error and phase error values. If a column of static-corrected apparent data is present in the avg file, SCSINV prompts you to choose either uncorrected or static-corrected values. Static-corrected apparent resistivities usually suppress the effects of near-surface features and clarify deeper structure. Inversions are often run on both uncorrected and static-corrected data sets. Controlled-source apparent resistivity data should be left in Cagniard apparent resistivity form, not “corrected” for near-field effects, since RSCSINV’s forward-modeling algorithm includes the effects of three-dimensional source fields and a finite transmitter-receiver separation.

Avg files are the preferred source for observed data, since they include measurement error information. However, SCSINV can also read Zonge format z files that hold CSAMT or AMT apparent resistivity and impedance phase data. z files must include matching apparent resistivity and impedance phase data blocks. z files do not include observed-data error estimates, so apparent resistivities are given a uniform measurement error of 5 percent and impedance phase an error of 50 mrad.

SCSINV gets station location information from optional stn files, which have columns of client station number, grid east, grid north and elevation. Station numbers should be in the final or “client” station number system defined by LblFrst and LblDelt in the mde file. Station numbers represent distance, possibly spaced irregularly, along a line, so SCSINV interpolates coordinates between tabulated station locations to fill in missing information. The minimum number of entries in a stn file are two points, the locations of the line’s first and last stations. Stn file grid coordinates should be in the same length units used to specify transmiiter and receiver dipole lengths. If no topographic information is available, stn file elevations may be set to zero. SCSINV then returns a model with layer mid-points specified relative to the ground’s surface. If no station file is present, SCSINV use default station location values.

After reading observed data and survey configuration information, SCSINV displays survey configuration parameters in an interactive dialog.



General information about the model may be stored in three text fields that are displayed at the top of the dialog box. Three menus are provided for selecting length units, survey type and transmitter type. Length units may be either metres or feet. Three choices are provided for the transmitter type, natural source, grounded bipole or an ungrounded horizontal loop.

If a bipole or loop controlled source is selected, then SCSINV exposes fields with values for transmitter location and orientation. The number of dialog box fields is adjusted to match the survey configuration specified by survey and transmitter types.

Descriptive Text fields allow you to save descriptive information within the SCSINV input file. Entries are saved as text within the scs file namelist block.

Length Units allows you to use either metres or feet for describing distances, coordinates and lengths.

Survey Type can be scalar, vector or tensor. All three survey types are equivalent in AMT modeling, but differ when inverting CSAMT data. Scalar means one transmitter and one receiver electromagnetic field polarization, vector is used for measurements using one transmitter and two receiver polarizations, while tensor indicates data derived from two transmitter and two receiver polarizations.

Transmitter Type specifies the source, Natural for plane wave, Bipole for grounded electric bipole or Loop for a horizontal loop.

Transmitter fields specify transmitter antenna parameters. Antenna length is given in distance units. Transmitter antenna azimuth is given in degrees clockwise from grid north, i.e. an east-west antenna has an azimuth of 90 degrees. The location of the transmitter must be specified with the same grid system used to locate receiver stations.

Receiver azimuth defaults to the transmitter azimuth unless a RxBrg is specified in the mde file. Receiver azimuths are in degrees clockwise from grid north.

The Tx-Rx Distance and Receiver Locations are displayed for reference only. The coordinates of the lowest and highest station numbers are shown. If values are incorrect, there is a problem with stn and or mde file entries and you should exit SCSINV to correct the problem before running an inversion. Positioning of the receiver relative to the transmitter bipole is important in controlled-source modeling.

Horizontal Smoothness Weighting allows you to adjust the importance of horizontal smoothness. Making the value smaller allows the model to vary more from station to station. Making the value larger forces a smoother model. The default value of 1.0 is good for most situations. Horizontal smoothness weighting is stored as dxWeight in the scs file namelist block.

Vertical Smoothness Weighting allows you to adjust the importance of vertical smoothness. Making the value smaller allows the model to vary more from layer to layer, while making the value larger forces a smoother model. The default value of 1.0 is good for most situations. A more through approach is to invert a data set using several different values of to examine the tradeoff between fitting observed data and maintaining model smoothness (see figure 2). Vertical smoothness weighting is stored as dzWeight in the scs namelist block.

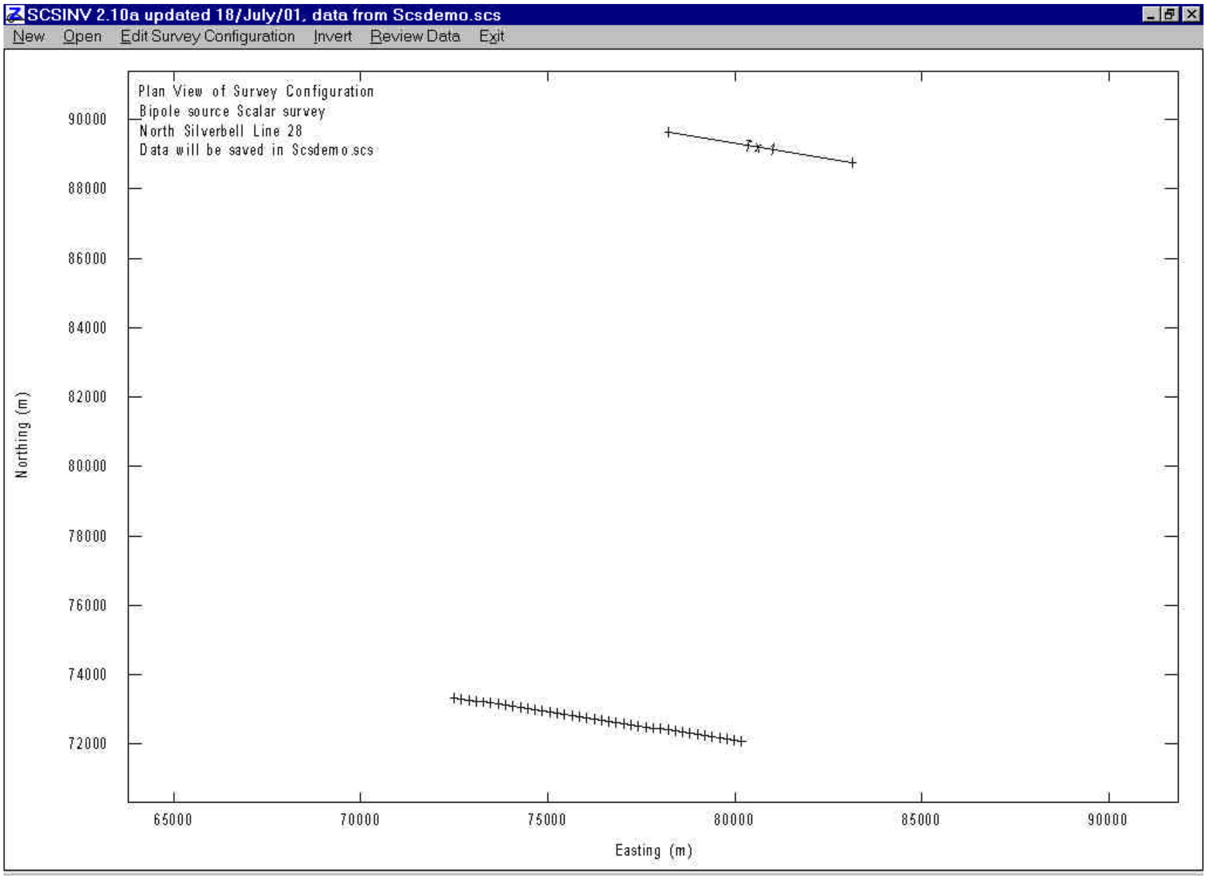
Observed Error Floor puts a lower limit on observed errors associated with each data point. Inversion results are often improved by limiting the smallest observed data error to five percent (50 mrad). Each calculated - observed data residual is weighted by the inverse of its associated error. Very small measurement errors for some data points can create excessively large weights.

Maximum Number of Iterations sets a ceiling on the number of iterations that RSCSINV.EXE will take during inversion. RSCSINV.EXE tests for convergence with each iteration and usually stops before the maximum number of iterations is reached.

Inversion-Data File Name allows you to change the scs directory path and file name. The maximum path + file name length is 128 characters. If the scs filename shown is unsatisfactory, clicking on the Save As button brings up an interactive dialog so that you can select a new directory or file name.

Clicking on the OK button indicates that you are satisfied with the information showing in the survey configuration dialog and SCSINV saves the information plus observed data to a scs file.

After SCSDEMO.SCS is created, SCSINV returns to the main menu and shows a schematic plan map of the survey area.



Station locations are indicated with + symbols and controlled-source bipole or loop antennas are shown as straight line segments derived from information in the survey configuration dialog. Transmitter location information may be corrected by selecting the Edit Survey Configuration menu item, which brings up the survey configuration dialog box you encountered while building a new model. Problems with station locations have to be corrected by editing the station file and rerunning SCSINV's New menu option.

If the plan map shows sounding stations and transmitter in the correct locations, then an inversion may be started by clicking on the Invert menu item. When Invert is selected, SCSINV starts program RSCSINV to do the numerically intensive work of inverting the data set to a smooth-model section.

Partial log from RSCSINV inversion of SCSDEMO.SCS:

```
RSCSINV v2.10a: CSAMT 1D Smooth-Model Inversion.
 Windows version implemented 18/July/01
 Zonge Engineering and Research
 Reading model parameter data from Scsdemo.scs
 Reading observed data from Scsdemo.scs
 Computing starting model . . .

 Station      -200.   Sweep  1  Iteration  0
 Data Residual:   15.705   Minimization Residual:   15.705

 Layer     Depth   Resistivity
 -----------------------------
    2        74.0       319.6
    4       183.1       319.6
    6       306.2       319.6
    8       445.0       319.6
   10       601.5       319.6
   12       777.9       319.6
   14       976.9       319.6

 Station      -200.   Sweep  1  Iteration  1
 Data Residual:    9.945   Minimization Residual:   10.426

 Layer     Depth   Resistivity
 -----------------------------
    2        74.0       194.9
    4       183.1       354.0
    6       306.2       665.6
    8       445.0      1022.7
   10       601.5      1305.5
   12       777.9      1356.5
   14       976.9      1375.3
    .          .          .
    .          .          .
    .          .          .
```

SCSINV sweeps back and forth along line, making a few iterations at each station, until the maximum number of sweep iterations (parameter Niteration in the scs file) has been reached.

In this example, RSCSINV.EXE inverts the data held in SCSDEMO.SCS and produces two files. SCSDEMO.M1D holds the smooth model parameters generated by the inversion (station, station location, elevation, model resistivity, model error and model sensitivity). SCSDEMO.OBS holds observed and calculated data in a tabular spreadsheet format. After RSCSINV has completed its inversion, it passes control back to SCSINV.

RSCSINV.EXE may also be run directly by typing "RSCSINV SCSDEMO.SCS" from the command line or from within a batch file. On a large project, is sometimes more efficient to use SCSINV to prepare a group of scs files and to then invert them using a batch file with repeated calls to RSCSINV, i.e:

```
start /w rscsinv scsdemo
start /w rscsinv yourscs1.scs
start /w rscsinv yourscs2.scs
```

The “`start /w rscsinv`” command starts RSCSINV running and instructs the operating system to wait until RSCSINV is finished before going to the next line in the batch file. RSCSINV looks for file names on its command line, allowing convenient batch file operation.

RSCSINV Inversion Criteria

RSCSINV attempts to simultaneously minimize both the difference between observed and calculated data, the difference between starting and inverted model parameters and inversion model roughness. These differences are mathematically summarized by sums of squared differences:

$$e_{total} = \sqrt{\left(e_{data}{}^2 + e_{model}{}^2\right)/nobs}$$

$$e_{data}{}^2 = \sum_{i=1}^{nobs}\left(\frac{d_{obs_i} - d_{mod_i}}{d_{err_i}}\right)^2$$

$$e_{model}{}^2 = dpW^2 \cdot \sum_{i=1}^{nz}\sum_{j=1}^{nx}\left(\frac{p_{i,j}^k - p_{i,j}^0}{p_{err_{i,j}}}\right)^2 + dxW^2 \cdot \sum_{i=1}^{nz}\sum_{j=2}^{nx}\left(p_{i,j}^k - p_{ij-1}^k\right)^2 + dzW^2 \cdot \sum_{i=2}^{nz}\sum_{j=1}^{nx}\left(p_{i,j}^k - p_{i-1,j}^k\right)^2$$

where

$nobs$ = number of observed data values.

d_{obs_i} = observed log(apparent resistivity) or impedance phase.

d_{mod_i} = calculated log(apparent resistivity) or impedance phase.

d_{err_i} = observed data error.

nx = number of stations in inversion model.

nz = number of layers per station in inversion model.

$p_{i,j}^0$ = starting model parameter, log(resistivity).

$p_{i,j}^k$ = inversion model parameter at iteration k, log(resistivity).

$p_{err_{i,j}}$ = inversion model error, log(resistivity).

dpW = dpWeight, relative weight given to starting model.

dxW = dxWeight, relative weight given to horizontal smoothness constraint.

dzW = dzWeight, relative weight given to vertical smoothness constraint.

RSCSINV reports e_{data}/sqrt(nobs) and e_{total} for a station after each inversion iteration**.** Model updates are not accepted if they increase e_{total}. If an inversion step fails to improve e_{total}, RSCSINV tries again using a more cautious step size. RSCSINV iterates on one station at a time, minimizing e_{total} for that station and its horizontal smoothness relative to neighboring stations. RSCSINV makes a few iterations at each station, then moves on to the next, sweeping back and forth along line a total of Niteration times.

Starting model importance can be increased or decreased by adjusting dpWeight in scs files. Default SCSINV starting-models are not weighted heavily. Starting-model resistivities are given an estimated error of 500 percent which is equivalent to $perr_{i,j}$ = 1.8 log(ohm-m) in the definition of e_{model}.

Model smoothness can be varied by changing the weight of dxWeight and dzWeight sums in e_{model} relative to the sum of (observed - calculated data)^2 in e_{data}. Increasing dzWeight by a factor of 10 in a scs file and then rerunning RSCSINV, increases the relative weight of the model's vertical smoothness constraint by a factor of 100, since dzW is squared in the definition for e_{model}.

Horizontal smoothness can be increased or decreased by adjusting dxWeight in scs files. Increasing horizontal smoothness might be desirable if data are collected in an area with flat lying geology.

The tradeoff between fitting observed data values and keeping the model as smooth as possible can be mapped by inverting a station or line with a range of dxWeight or dzWeight values.

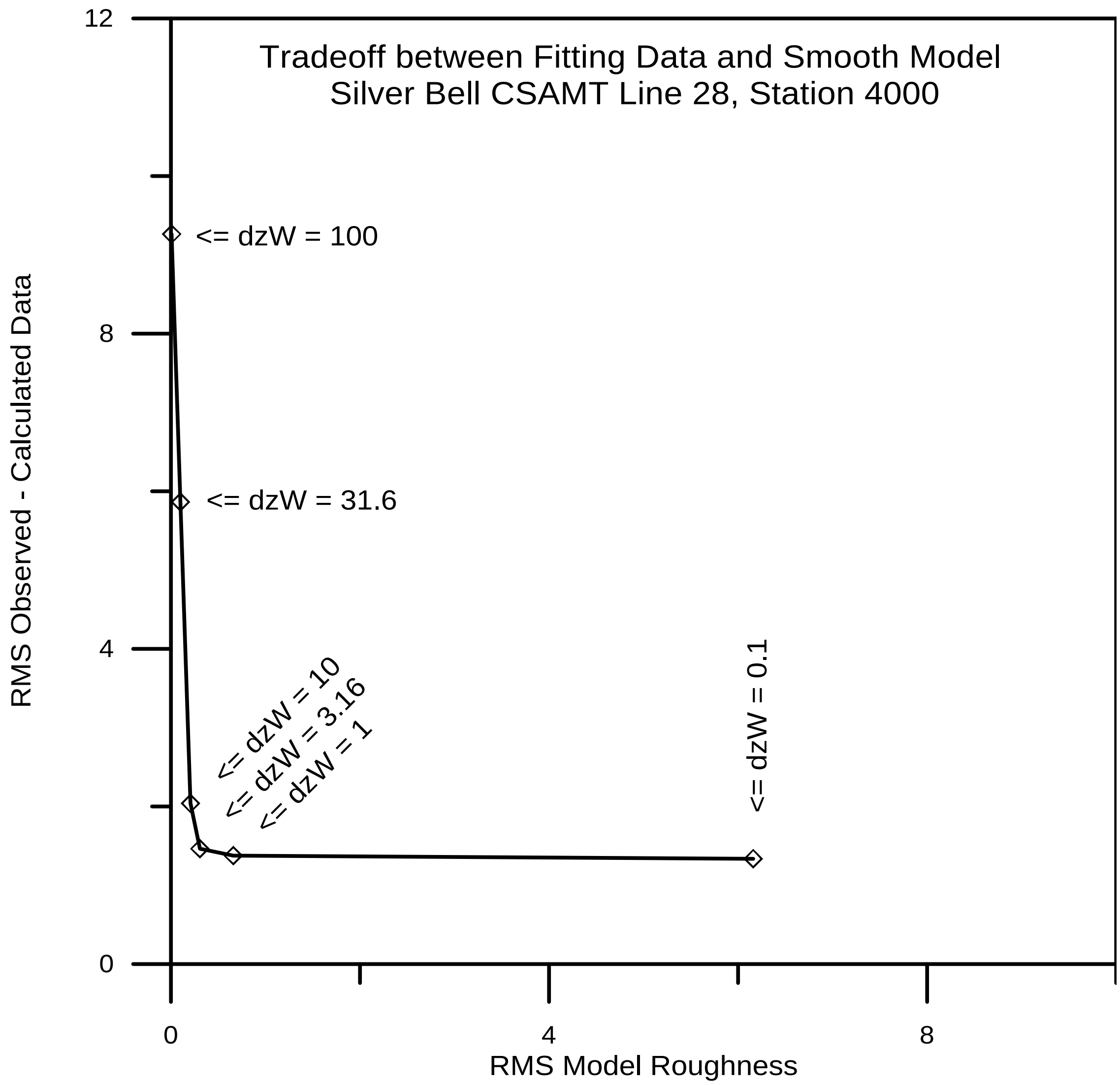
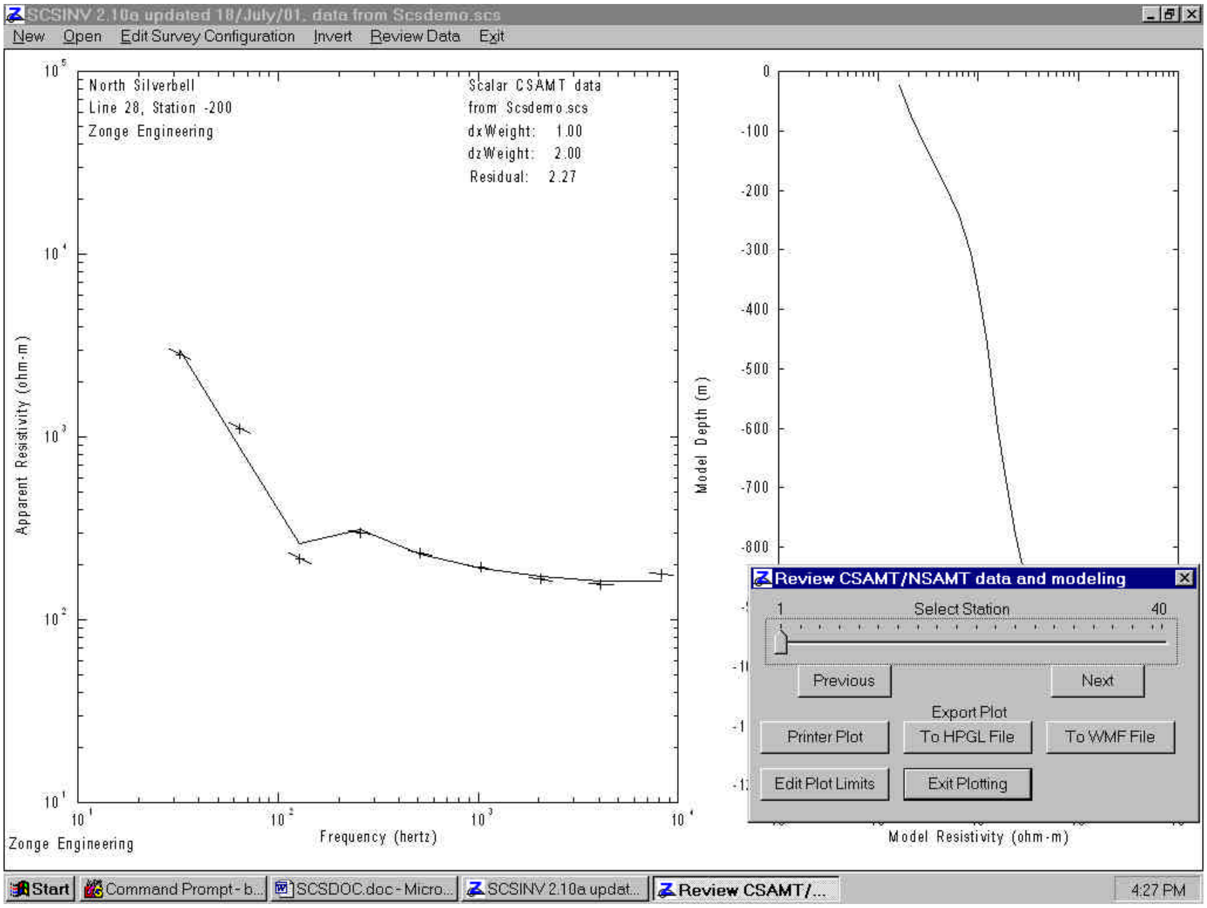


Figure 2: Inverting data for a single station with different values for dzWeight shows the tradeoff between fitting observed data and keeping model smoothness. Data from station 4000 in SCSDEMO.SCS were inverted with dzWeight varying between 100 and 0.1. Plotting RMS (root-mean-square) observed - calculated data residuals versus RMS model roughness shows how a dzWeight=100 returns a poorly fitting, but very smooth model. Conversely, using dzWeight = 0.1 gives a good fit to observed data, but the inverted model is not smooth. Using dzWeight = 3 is nearly optimal, returning both a good fit to observed data and a smooth model.

After the inversion is complete, you may review inversion results on a station-by-station basis with the Review Data menu option, which generates log-log plots of observed and calculated apparent resistivity versus frequency and log-linear plots of model resistivity versus elevation.



In the left plot panel, observed apparent resistivities are marked by the intersection of a sloping horizontal line based on impedance phase and a vertical line scaled by measurement error. Calculated apparent resistivities are indicated by a solid curve. Smooth-model resistivities are shown in the right panel as a log-linear plot of resistivity versus depth.

A small dialog box pops up to allow control of Review Data plots. Stations may be selected for display by clicking on the Previous or Next buttons or by moving the trackbar slider. {To adjust the trackbar slider, move the mouse cursor over the slider, then hold down the left mouse button while you move the slider sideways.} The dialog box may be moved around on the screen to expose hidden plot sections. Plots may be exported to the printer for hardcopy with the Printer Plot button or saved in plot files for later use with the To HPGL File or To WMF File buttons. SCSINV generates plot file names which include sequential numbers indicating each sounding's location along line, starting with 001 for the first station. HPGL (HP graphics language) files can by imported or plotted by many graphics programs. WMF (windows metafile) files may be pasted into MS Word documents and are useful for report writing.

Working from left to right along the main menu options takes you through the model building, inversion and review sequence in an ordered manner. Additional models may be generated by selecting New or you can close SCSINV by choosing Exit.

Both m1d and obs files are in a tabular format that can be read directly by most general purpose contouring packages. Zonge utility program MODSECT may be used to generate color-filled inversion model sections. It includes options for printing model-section plots, exporting to hpgl or wmf plot files, generating Surfer script and data files, or creating Oasis montaj script and data files.

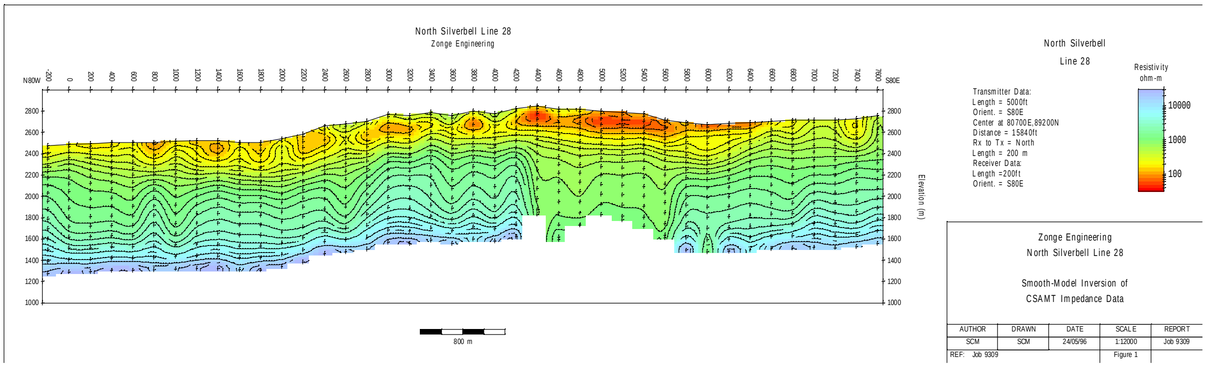


Figure 3: Smooth-model cross section from inversion of SCSDEMO.SCS using dzWeight = 3.0. MODSECT was used to plot the smooth-model section and save it in a wmf.

References

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Data Processing File Documentation

MDE file - line annotation, survey configuration and data processing control

Partial listing of SCSDEMO.MDE:

```
$  CLIENT=Zonge Engineering
$ PROJECT=North Silverbell
$ JOBNUMB= 9309
$ JOBDATE=Nov 93
$ JOBLINE=28
$ BRGLINE=S80E
$ BRGBACK=N80W
$   UNITS=  FEET
$ STNLO  =    -2.0
$ STNDELT=     2.0
$ LBLFRST=    -200.0
$ LBLDELT=     200.0
$  TXTYPE= Bipole
$   TXLEN= 5000
$   TXBRG= S80E
$   TXCX =80700
$   TXCY =89200
$   TXDIS=15840
$   RX2TX= North
$   RXBRG=S80E
$   RXLEN=200
```

Mde files hold annotation information about each line, survey configuration parameters and Zonge Engineering data processing control parameters. A mde file consists of one or more “mode” lines, each of which begins with a "$" in the first column, optionally followed by a program name and colon ":". The name of the mode keyword is followed by an equal sign "=", then the value to assign to the variable. Spaces may be included between the elements of the mode line. Spaces in values defined as text will be included as part of the value.

STNLO, LBLFRST, STNDELT and LBLDELT can be used to shift and scale station numbers from values used in raw, avg and z files to some other station number system. STNLO and LBLFRST may be used to define a station number shift. STNDELT and LBLDELT may be used to scale station numbers. Default values produce no station number shifting or scaling.

STNLO - first GDP station number (GDP station numbers are used in raw, avg and z files).
LBLFRST - first client station number (client stn #s are used in modeling files and on plots).
STNDELT - GDP station number increment.
LBLDELT - client station number increment.

The following mode keywords are used by SCSINV for default positioning and orientation of the transmitter antenna.

UNITS - length units (m, ft).
TXTYPE - transmitter type (bipole,loop,natural).
TXLEN - transmitter bipole length or loop length and width (length units).
TXBRG - transmitter antenna bearing in N??E format or azimuth.
TXCX - transmitter antenna center grid E coordinate (units).
TXCY - transmitter antenna center grid N coordinate (units).
TXDIS - distance from line center to transmitter center (units).
RX2TX - bearing from line center to transmitter center in N??E format or azimuth.
RXBRG - receiver E-field bearing in scalar surveys in N??E format or azimuth.
RXLEN - receiver dipole length (length units).

These modes are used to control plot annotation, scaling and color fill when making smooth-model-section plots with Zonge utility program MODSECT.

```
$ MODSECT: PlotExport = Surfer
$ MODSECT: LNUNITS = m
$ MODSECT: LNTITLE1 = North Silverbell Line 28
$ MODSECT: LNTITLE2 = Zonge Engineering
$ MODSECT: BRGLEFT= N80W
$ MODSECT: BRGRIGHT= S80E
$ MODSECT: TBTITLE1 = Zonge Engineering
$ MODSECT: TBTITLE2 = North Silverbell Line 28
$ MODSECT: TBTITLE3 =
$ MODSECT: TBTITLE4 = Smooth-Model Inversion of
$ MODSECT: TBTITLE5 = CSAMT Impedance Data
$ MODSECT: TBLABEL1 = AUTHOR
$ MODSECT: TBLABEL2 = DRAWN
$ MODSECT: TBLABEL3 = DATE
$ MODSECT: TBLABEL4 = SCALE
$ MODSECT: TBLABEL5 = REPORT
$ MODSECT: TBLABEL6 = REF:
$ MODSECT: TBTEXT1 = SCM
$ MODSECT: TBTEXT2 = SCM
$ MODSECT: TBTEXT3 = 24/05/96
$ MODSECT: TBTEXT4 = 1:24000
$ MODSECT: TBTEXT5 = Job 9309
$ MODSECT: TBTEXT6 = Job 9309
$ MODSECT: TBTEXT7 = Figure 1
$ MODSECT: TBGLOSS01 = Transmitter Data:
$ MODSECT: TBGLOSS02 = Length = 5000ft
$ MODSECT: TBGLOSS03 = Orient. = S80E
$ MODSECT: TBGLOSS04 = Center at 80700E,89200N
$ MODSECT: TBGLOSS05 = Distance = 15840ft
$ MODSECT: TBGLOSS06 = Rx to Tx = North
$ MODSECT: TBGLOSS07 = Length = 200 m
$ MODSECT: TBGLOSS08 = Receiver Data:
$ MODSECT: TBGLOSS09 = Length =200ft
$ MODSECT: TBGLOSS10 = Orient. = S80E
$ MODSECT: XSCALE =   2.4000E+4   Horizontal scale  (plot X-axis)
$ MODSECT: YSCALE =   2.4000E+4   Vertical scale    (plot Y-axis)
$ MODSECT: YSIZE  =       14.00   Min plot height including margins (cm)
$ MODSECT: StnLeft  =     -200.   First station on left edge of plot
$ MODSECT: StnRight =     7600.   Last station on right edge of plot
$ MODSECT: StnDec   =      0      # station-number decimals (0 to 3)
$ MODSECT: StnInc   =    200.00   Station interval (stn #)
$ MODSECT: ElvMin   =   1000.00   Minimum elevation (plot Y-axis)
$ MODSECT: ElvMax   =   3000.00   Maximum elevation (plot Y-axis)
$ MODSECT: ElvInc   =    200.00   Elevation tick interval
$ MODSECT: TOPO   = YES           Draw line along topographic surface?
$ MODSECT: CNTVAR = Resistivity  Contour variable (resistivity or IP)
$ MODSECT: CRMIN  =        1.50   Res contour color minimum (log10(ohm-m))
$ MODSECT: CRMAX  =        4.50   Res contour color maximum (log10(ohm-m))
$ MODSECT: CRINC  =        0.10   Res contour interval (log10(ohm-m))
$ MODSECT: CRDEC  =        0      # res-contour-label decimals (0 to 3)
$ MODSECT: RScutoff =      0.01   Resistivity-sensitivity cutoff (percent)
```

AVG file - averaged CSAMT data and measurement error estimates

Partial listing of SCSDEMO.AVG file:

```
\ AMTAVG 7.20: "L28.FLD", Dated 93-11-17, Processed 19 Nov 93
\$ ASPACE=  200.ft
\$ XMTR  =    1.
\ ASTATIC v2.01 added TMARES/SRES column on 05/24/96
\ 5-point TMA Filter at 4096 hertz
skp Station Freq  Comp Amps     Emag     Ephz     Hmag    Hphz  Resistivity  Phase  %Emag  sEphz  %Hmag  sHphz   %Rho   sPhz TMARES/SRES
 2    0.   8192 ExHy  7.   7.1637e+3 -2555.4  2.6594e+0  3089.1  1.7716e+2   638.6   0.4   4.4   0.1   10.1   0.9   7.2  1.6584E+2
 2    0.   4096 ExHy 11.   6.6556e+3 -1749.9  3.5677e+0 -2371.4  1.6993e+2   621.6   0.1   1.8   0.8    8.3   0.8   9.9  1.5907E+2
 2    0.   2048 ExHy 16.   6.8889e+3 -1180.6  4.9804e+0 -1780.0  1.8684e+2   599.4   0.3   2.5   0.2    3.1   0.3   3.3  1.7490E+2
 2    0.   1024 ExHy 20.   7.2575e+3  -795.0  6.9107e+0 -1365.8  2.1540e+2   570.8   0.2   2.0   0.2    2.4   0.7   6.0  2.0164E+2
 2    0.    512 ExHy 22.   7.6680e+3  -608.6  9.5484e+0 -1141.3  2.5192e+2   532.7   0.7   7.2   0.1    1.6   1.2   8.6  2.3582E+2
 2    0.    256 ExHy 22.   8.5168e+3  -450.5  1.3391e+1 -1021.6  3.1604e+2   571.1   0.2   1.5   0.4    4.9   0.6   6.4  2.9585E+2
 2    0.    128 ExHy 22.   8.5507e+3 -1113.6  2.2357e+1 -1091.8  2.2856e+2   -21.8   0.3   2.4   0.5    3.3   0.5   1.1  2.1396E+2
 2    0.     64 ExHy 22.   2.4669e+4  -950.4  4.0949e+1  -769.0  1.1341e+3  -181.4   0.1   1.1   0.4    3.9   0.8   1.5  1.0616E+3
 2    0.     32 ExHy 22.   3.6149e+4  -357.9  5.3420e+1  -291.1  2.8619e+3   -66.8   0.1   0.9   0.4    4.3   0.6   2.9  2.6790E+3
 2    2.   8192 ExHy  7.   6.4907e+3 -2597.9  2.6594e+0  3089.1  1.4544e+2   596.1   0.3   4.0   0.1   10.1   0.9   7.4  1.5724E+2
 2    2.   4096 ExHy 11.   6.1855e+3 -1740.7  3.5677e+0 -2371.4  1.4677e+2   630.8   0.0   0.9   0.8    8.3   0.6   8.4  1.5867E+2
 2    2.   2048 ExHy 16.   6.3995e+3 -1155.5  4.9804e+0 -1780.0  1.6124e+2   624.4   0.2   1.7   0.2    3.1   0.3   3.0  1.7432E+2
 2    2.   1024 ExHy 20.   6.6290e+3  -759.6  6.9107e+0 -1365.8  1.7971e+2   606.2   0.1   1.1   0.2    2.4   0.5   4.4  1.9428E+2
 2    2.    512 ExHy 22.   6.8992e+3  -571.8  9.5484e+0 -1141.3  2.0394e+2   569.5   0.4   4.8   0.1    1.6   0.7   5.1  2.2048E+2
 2    2.    256 ExHy 22.   7.4206e+3  -413.4  1.3391e+1 -1021.6  2.3992e+2   608.2   0.2   1.3   0.4    4.9   0.6   6.5  2.5938E+2
 2    2.    128 ExHy 22.   7.3464e+3 -1077.4  2.2357e+1 -1091.8  1.6871e+2    14.5   0.3   3.3   0.5    3.3   0.6   0.2  1.8239E+2
 2    2.     64 ExHy 22.   2.0806e+4  -925.6  4.0949e+1  -769.0  8.0672e+2  -156.6   0.1   1.1   0.4    3.9   0.8   1.5  8.7214E+2
 2    2.     32 ExHy 22.   3.0245e+4  -345.0  5.3420e+1  -291.1  2.0034e+3   -53.8   0.1   0.8   0.4    4.3   0.6   2.8  2.1659E+3
 2    4.   8192 ExHy  7.   6.5220e+3 -2632.8  2.6594e+0  3089.1  1.4684e+2   561.2   0.3   3.9   0.1   10.1   0.9   7.4  1.5280E+2
 2    4.   4096 ExHy 11.   6.2180e+3 -1734.0  3.5677e+0 -2371.4  1.4832e+2   637.4   0.0   0.6   0.8    8.3   0.6   7.9  1.5434E+2
 2    4.   2048 ExHy 16.   6.3449e+3 -1132.1  4.9804e+0 -1780.0  1.5850e+2   647.8   0.1   1.2   0.2    3.1   0.3   2.7  1.6493E+2
 2    4.   1024 ExHy 20.   6.4338e+3  -728.9  6.9107e+0 -1365.8  1.6928e+2   636.9   0.1   0.7   0.2    2.4   0.4   3.8  1.7615E+2
 2    4.    512 ExHy 22.   6.5959e+3  -543.1  9.5484e+0 -1141.3  1.8640e+2   598.2   0.3   3.8   0.1    1.6   0.5   3.7  1.9397E+2
 2    4.    256 ExHy 22.   6.9569e+3  -387.4  1.3391e+1 -1021.6  2.1087e+2   634.2   0.1   1.3   0.4    4.9   0.6   6.7  2.1943E+2
 2    4.    128 ExHy 22.   6.9105e+3 -1043.6  2.2357e+1 -1091.8  1.4929e+2    48.2   0.4   4.4   0.5    3.3   0.7   1.8  1.5535E+2
 2    4.     64 ExHy 22.   1.8971e+4  -894.2  4.0949e+1  -769.0  6.7075e+2  -125.2   0.1   1.1   0.4    3.9   0.8   1.5  6.9798E+2
```

An avg file contains averaged CSAMT data for discrete frequencies. CSAMT avg files are produced by the Zonge data processing program AMTAVG, which reads files with repeat readings, averages them and calculates measurement error from variation between repeats. Avg files are archived together with GDP-format files (raw) and station location files (stn). avg files are used by programs that provide plot files, options for further data processing, or modeling.

Comment lines preceded by a "\", "/", "!" or """ in column 1 may be placed anywhere within avg files. Data processing mode lines preceded by a "$" in column 1 may also be present. A line holding column labels must precede the numerical data. Column order is not fixed and all columns may not be present in a particular file. Missing values are flagged by a "*". Numerical values are free format with columns separated by spaces or commas.

CSAMT avg file column definitions:

Skp - skip flag, 2 = good data, 1= bad data, 0 = very bad data.
Station - receiver station number in unscaled and unshifted units.
Comp - measured E and H field component pair (ExHy or EyHx).
Amps - peak-to-peak square-wave current = pi/4*Fourier component current (amps).
Freq. - measurement frequency (hertz).
Emag - electric-field magnitude (uV/(km*amp)=nV/(m*amp)).
Ephz - electric-field phase (mrad).
Hmag - magnetic-field magnitude (pT/amp).
Hphz - magnetic-field phase (mrad).
Resistivity - Cagniard resistivity (ohm-m) .
Phase - impedance phase = phase(E/H) (mrad).
%Emag - E-field magnitude error = 100*standard_deviation(Emag)/Emag (percent).
sEphz - E-field phase error = 100*standard_deviation of Ephz (mrad).
sHphz - H-field phase error = 100*standard_deviation of Hphz (mrad).
%Hmag - H-field magnitude error = 100*standard_deviation(Hmag)/Hmag (percent).
%Rho - apparent resistivity error = 100*standard_deviation(Rho)/Rho (percent).
sPhz - impedance phase error = standard deviation (mrad).
TMARES/SRES - static-corrected apparent resistivity (ohm-m) (added by ASTATIC).

Z file - averaged CSAMT data

Partial listing of z file:

```
$ ZPLOT: DATA = FLOG
$ ASPACE =    60.960m
 Contour Plot Z-File
 Cl Cn Ce Ns Nd Yl  Plot file  1
  1  5  0  3  1  1
 CSAMT SURVEY DATA
 STATIC-CORRECTED APP. RES.
 5-point TMA Filter at 4096 hertz
 ASTATIC v2.01a 05/24/96
IIxxxxxxxxYYYYYYYYzzzzzzzzzzzz
 2     -2.  14.000    2.832E+3
 2     -2.  15.000    1.113E+3
 2     -2.  16.000    2.168E+2
 2     -2.  17.000    2.999E+2
 2     -2.  18.000    2.307E+2
 2     -2.  19.000    1.941E+2
 2     -2.  20.000    1.666E+2
 2     -2.  21.000    1.567E+2
 2     -2.  22.000    1.772E+2
 2      0.  14.000    2.679E+3
 2      0.  15.000    1.062E+3
 .      .     .        .
 .      .     .        .
 .      .     .        .
 2     76.  20.000    2.448E+2
 2     76.  21.000    2.387E+2
 2     76.  22.000    2.530E+2
 9999.00
 Cl Cn Ce Ns Nd Yl  Plot file  2
  0 10  3  3  0  1
 CSAMT SURVEY DATA
 IMPEDANCE PHASE
 values in milliradians
IIxxxxxxxxYYYYYYYYzzzzzzzzzzzz
 2     -2.  14.000   -7.650E+1
 2     -2.  15.000   -1.974E+2
 2     -2.  16.000   -3.920E+1
 .      .     .        .
 .      .     .        .
 .      .     .        .
 2     76.  20.000    6.787E+2
 2     76.  21.000    6.589E+2
 2     76.  22.000    6.129E+2
 9999.00
```

z files are used for storing plot file data in multiple (skp,x,y,z) data blocks. Numerical values are stored in a fixed format, so column position is important. Numerical field widths are indicated by the “IxYz” record preceding numerical data. A “IxYz” record flags the beginning of a block of numerical (skp,x,y,z) data and a 9999.0 value flags the end of the block. For CSINV input, the z file must have both apparent resistivity and impedance phase data blocks. Apparent resistivities may be uncorrected, static-corrected or filtered.

Description of lines in sample z file:

$ ZPLOT: DATA= FLOG - mode line, y-value data type (log(freq))
$ ASPACE = 60.960m - receiver dipole length
AMTAVG 7.20 - program name and version that generated this file.
Cl Cn Ce Ns Nd Yl - labels for integer contour control flags.
Cl - label for contour type: 0 = linear
1 = logarithmic
2 = pseudo-log: Pseudo-log contours = positive and negative values are contoured separately, using log10(abs(value)), plus a zero contour.
Cn - label for number of contours per interval.
Ce - label for exponent of the contour interval, interval=10^Ce.
Ns - label for number of significant digits when posting values.
Values: -1, 3, 4, 5. (-1 = free format for small values)
Nd - label for the number of digits after the decimal.
Yl - label for vertical axis: 0 = none
1 = log frequency axis
2 = linear frequency axis
3 = linear depth
1 5 0 3 1 1 - integer values for contour control flags.
1 - value of Cl => logarithmic contours
5 - value of Cn => 5 contours per "interval"
0 - value of Ce => interval=10 <= > Ce=1
3 - value of Ns => use 3 significant digits for contouring
1 - value of Nd => plot 1 digit after the decimal
1 - value of Yl => log frequency axis
CSAMT SURVEY DATA - Data description for this plot file. Two to six lines are available.
CAGNIARD APP. RES. Column one is not read by ZPLOT.
values in ohm-m ZPLOT plots these lines as title annotation.
Data from ASTDEMO.AVG
IIxxxxxxxxYYYYYYYYzzzzzzzzzzzz - Header line for the data that follows.
II - skip flag field:
0 = Skip this line of data.
1 = Omit for contouring, but post the bracketed value.
2 = Use for contouring and post the value (most common).
3 = Label a point or station by plotting a symbol under the X-axis at the X-coordinate.
4 = Use for contouring, post the symbol and not the value. Used for depth plots where interpolated values are used at the bottom of the plot to improve gridding.
5 = Use to set plot limits, do not contour or post. Used for depth plots to set zero depth. Also used to provide a margin around the data, as for plan maps.
xxxxxxxx - x value field, usually unscaled and unshifted station numbers.
YYYYYYYY - y value field, for CSAMT y=log2(freq)-9, not used when skip flag = 3
zzzzzzzzzzzz - z value field, to be plotted at (x,y) when skip flag=1, 2, or 4.
AAA - annotation field, when skip flag=1 or 2, ZPLOT posts any characters in the AAA column instead of plotting the z value. When skip flag=3, ZPLOT plots a symbol below the x-axis at the x-value according to an integer in column AAA. A zero or positive integer refers to symbols in TABLE 1 of the PLOT Manual. A negative integer refers to topographic symbols in the CTOPO Manual.
9999.0 - marks end of (stn,x,y,z) data block.

STN file - station location and elevation

Listing of SCSDEMO.STN:

```
\Stn        GridE    GridN Elevation
    -200    72490    73343     2475
       0    72687    73311     2490
     200    72885    73279     2495
     400    73082    73246     2505
     600    73280    73214     2505
     800    73477    73182     2510
    1000    73674    73149     2520
    1200    73872    73117     2525
    1400    74069    73085     2525
    1600    74266    73052     2510
    1800    74464    73020     2508
    2000    74661    72988     2540
      .        .        .          .
      .        .        .          .
      .        .        .          .
    7200    79792    72147     2718
    7400    79990    72115     2730
    7600    80187    72083     2760
```

stn files hold information about station locations in a tabular format. A stn file should have at least two entries, corresponding to the first and last stations. Additional entries may be necessary to trace out topographic changes or curved lines. SCSINV assumes that station numbers represent distance along line and uses station numbers to interpolate coordinates of stations without a matching entry in the stn file. If station numbers are scaled by entries in the mde file, stn-file station numbers should be in the scaled and shifted units defined by mde LBLFRST and LBLDELT, not the unscaled and unshifted units defined by STNBEG, STNDELT.

Some grid coordinate systems, such as UTM coordinates, can generate very large coordinate values. SCSINV stores station locations as floating-point numbers with about six significant figures. It may be necessary to subtract a constant from large coordinate values in order to allow accurate representation with six significant figures.

stn file column definitions:

Stn - station numbers. Station numbers can be in any unit, but they should be proportional to distance along line.
GridE - grid east (LengthUnits).
GridN - grid north (LengthUnits).
Elev - elevation (LengthUnits).

SCSINV File Documentation

SCS file - survey configuration, inversion control and observed data

Partial Listing of SCSDEMO.SCS:

```
&SCSINV
Header(1)='From SCSINV v2.10a  Date:18/07/01  Time:15:41:56'
Header(2)='North Silverbell  Line 28'
Header(3)='for Zonge Engineering'
Header(4)='Data from D:\MODELING\AMT\Scsinv\Scsinv\scsinv\Scsdemo.avg'
SurveyType='Scalar',TxType='Bipole',LengthUnits='m',
TxLength(1)=5000,TxAzimuth(1)=100,TxGridE(1)=80700,TxGridN(1)=89200,
RxLength(1)=200,RxAzimuth(1)=100,
dpWeight=1.00,dxWeight=1.00,dzWeight=2.00,Niteration=10,
/ "Stn"       "GridE"  "GridN" "Elev" "Freq"  "ARobs" "ARerr" "PZobs"
"PZerr"
     -400.    72293    73375   2460  32.00     2832.       5   -77  50
     -400.    72293    73375   2460  64.00     1113.       5  -197  50
     -400.    72293    73375   2460  128.0     216.8       5   -39  50
     -400.    72293    73375   2460  256.0     299.9       5   556  50
     -400.    72293    73375   2460  512.0     230.7       5   519  50
     -400.    72293    73375   2460  1024.     194.1       5   568  50
     -400.    72293    73375   2460  2048.     166.6       5   620  50
     -400.    72293    73375   2460  4096.     156.7       5   676  50
     -400.    72293    73375   2460  8192.     177.1       5   663  50
     -200.    72490    73343   2475  32.00     2679.       5   -67  50
     -200.    72490    73343   2475  64.00     1062.       5  -181  50
     -200.    72490    73343   2475  128.0     214.0       5   -22  50
     -200.    72490    73343   2475  256.0     295.9       5   571  50
     -200.    72490    73343   2475  512.0     235.8       5   533  50
     -200.    72490    73343   2475  1024.     201.6       5   571  50
     -200.    72490    73343   2475  2048.     174.9       5   599  50
     -200.    72490    73343   2475  4096.     159.1       5   622  50
     -200.    72490    73343   2475  8192.     165.8       5   639  50
        0.    72687    73311   2490  32.00     2166.       5   -54  50
        0.    72687    73311   2490  64.00     872.1       5  -157  50
        0.    72687    73311   2490  128.0     182.4       5    15  50
        .        .        .      .      .         .        .     .   .
        .        .        .      .      .         .        .     .   .
        .        .        .      .      .         .        .     .   .
     7400.    79990    72115   2730  2048.     244.8       5   679  50
     7400.    79990    72115   2730  4096.     238.6       5   659  50
     7400.    79990    72115   2730  8192.     253.0       5   613  50
```

SCSINV Fortran Namelist block:

Header(1)	- program name, version, date, and time.
. . . . . .	- free format text describing model.
Header(4)	- up to four header lines can be included.
LengthUnits	- character, distance units (m or ft).
SurveyType	- character, 'Scalar', 'Vector' or 'Tensor'.
TxType	- character, 'Natural', 'Bipole' or 'Loop'.
TxLength	- real array, length of transmitter bipole (LengthUnits).
TxAzimuth	- real array, azimuth of transmitter antenna (degrees east of north).
TxGridE	- real array, grid east coordinates of Tx center (LengthUnits).
TxGridN	- real array, grid north coordinates of Tx center (LengthUnits).
RxAximuth	- real array, azimuth of Rx E-field in scalar survey (deg east of north).
Niteration	- integer, number of restarts to use in iterative inversion.
dpWeight	- relative weight of starting model (default=1.0).
dxWeight	- relative weight of horizontal smoothness constraints (default=1.0).
dzWeight	- relative weight of vertical smoothness constraints (default=1.0).
/	- marks end of namelist input block.

Observed Data Columns:

Column 1	- station number.
Column 2	- station grid-east coordinate (m or ft) (LengthUnits).
Column 3	- station grid-north coordinate (m or ft) (LengthUnits).
Column 4	- station elevation (m or ft) (+ upwards, LengthUnits).
Column 5	- frequency (hertz), ordered low to high for each station.
Column 6	- observed apparent resistivity (ohm-m).
Column 7	- relative resistivity error (percent).
Column 8	- observed impedance phase (mrad).
Column 9	- impedance phase error (mrad).

M1D file - inversion model

Partial Listing of SCSDEMO.M1D:

```
"Stn" "GridE" "GridN" "Zinv" "ResInv" "Res0" "Rerr0" "Rerr" "Rsns"
    -400.    72293    73375   2460  148.2     288.9      500.0    24.4   94.99
    -400.    72293    73375   2435  148.2     288.9      500.0    24.4   94.99
    -400.    72293    73375   2380  170.9     288.9      500.0    29.4   56.28
    -400.    72293    73375   2316  189.0     288.9      500.0    30.7   46.00
    -400.    72293    73375   2239  212.0     288.9      500.0    30.5   42.68
    -400.    72293    73375   2148  262.7     288.9      500.0    33.2   42.14
    -400.    72293    73375   2040  357.5     288.9      500.0    37.4   30.14
    -400.    72293    73375   1913  478.7     288.9      500.0    41.1   28.19
    -400.    72293    73375   1762  568.2     288.9      500.0    42.8   28.98
    -400.    72293    73375   1583  588.2     288.9      500.0    42.6   27.08
    -400.    72293    73375   1370  565.2     288.9      500.0    41.5   29.40
    -400.    72293    73375   1119  551.0     288.9      500.0    40.1   38.53
    -400.    72293    73375    821  583.3     288.9      500.0    38.2   33.57
    -400.    72293    73375    468  681.1     288.9      500.0    37.3   31.14
    -400.    72293    73375    440  681.1     288.9      500.0    37.3   31.14
    -200.    72490    73343   2475  133.7     279.0      500.0    21.3   96.33
    -200.    72490    73343   2450  133.7     279.0      500.0    21.3   96.33
    -200.    72490    73343   2395  168.1     279.0      500.0    28.2   59.66
      .        .        .      .     .          .          .        .      .
      .        .        .      .     .          .          .        .      .
      .        .        .      .     .          .          .        .      .
    7400.    79990    72115   1389  470.9     316.2      500.0    39.3   38.83
    7400.    79990    72115   1185  494.1     316.2      500.0    37.1   33.20
    7400.    79990    72115   1185  494.1     316.2      500.0    37.1   33.20
```

m1d files hold layer model parameters. RCSINV will update a m1d file if it already exists, otherwise it creates one. Numerical values are arranged in free-format columns separated by commas or spaces. Column spacing is not important, but column order is critical. Comment lines starting with a “\”, “/”, “!” or “”” character in column 1 or 2 may be placed anywhere within m1d files.

m1d-file column definitions :

- Stn - station numbers. Station numbers may be in arbitrarily scaled units, but they should be roughly proportional to distance along line.
- GridE - grid east (LengthUnits).
- GridN - grid north (LengthUnits).
- Zinv - layer midpoint elevations (LengthUnits) (if station elevations=0, RSCSINV returns layer elevations as depths, depth = elevation relative to surface).
- ResInv - layer resistivity (ohm-m).
- Rerr0 - starting model layer resistivity error (percent).
- Rerr - linear estimate of inverted model layer resistivity error (percent).
- Rsns - normalized layer-resistivity sensitivity or importance (percent).

OBS file - observed and calculated data

Partial Listing of SCSDEMO.OBS:

"Stn"	"GridE"	"GridN"	"Elev"	"Freq"	"ARobs"	"ARerr"	"PZobs"	"PZerr"	"ARcalc"	"PZcalc"
-400.	72293	73375	2460	32.00	2832.	5	-77	50	1971.	44
-400.	72293	73375	2460	64.00	1113.	5	-197	50	969.4	-6
-400.	72293	73375	2460	128.0	216.8	5	-39	50	339.6	-8
-400.	72293	73375	2460	256.0	299.9	5	556	50	186.5	671
-400.	72293	73375	2460	512.0	230.7	5	519	50	254.8	601
-400.	72293	73375	2460	1024.	194.1	5	568	50	222.1	615
-400.	72293	73375	2460	2048.	166.6	5	620	50	188.0	638
-400.	72293	73375	2460	4096.	156.7	5	676	50	166.5	684
-400.	72293	73375	2460	8192.	177.1	5	663	50	158.2	726
-200.	72490	73343	2475	32.00	2679.	5	-67	50	1878.	116
-200.	72490	73343	2475	64.00	1062.	5	-181	50	1003.	74
-200.	72490	73343	2475	128.0	214.0	5	-22	50	417.4	69
-200.	72490	73343	2475	256.0	295.9	5	571	50	206.6	542
-200.	72490	73343	2475	512.0	235.8	5	533	50	253.7	541
-200.	72490	73343	2475	1024.	201.6	5	571	50	206.6	586
-200.	72490	73343	2475	2048.	174.9	5	599	50	176.8	638
-200.	72490	73343	2475	4096.	159.1	5	622	50	161.8	683
-200.	72490	73343	2475	8192.	165.8	5	639	50	152.9	709
0.	72687	73311	2490	32.00	2166.	5	-54	50	1677.	90
0.	72687	73311	2490	64.00	872.1	5	-157	50	864.3	43
0.	72687	73311	2490	128.0	182.4	5	15	50	329.5	47
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
7400.	79990	72115	2730	2048.	244.8	5	679	50	250.4	725
7400.	79990	72115	2730	4096.	238.6	5	659	50	245.3	720
7400.	79990	72115	2730	8192.	253.0	5	613	50	233.0	688

Observed Data Columns (columns 1 through 9 are the same as scs files):

Column 1 - station number.
Column 2 - station grid-east coordinate (m or ft) (LengthUnits).
Column 3 - station grid-north coordinate (m or ft) (LengthUnits).
Column 4 - station elevation (m or ft) (+ upwards, LengthUnits).
Column 5 - frequency (hertz), ordered low to high for each station.
Column 6 - observed apparent resistivity (ohm-m).
Column 7 - relative resistivity error (percent).
Column 8 - observed impedance phase (mrad).
Column 9 - impedance phase error (mrad).
Column 10 - calculated apparent resistivity (ohm-m).
Column 11 - calculated impedance phase (mrad).