

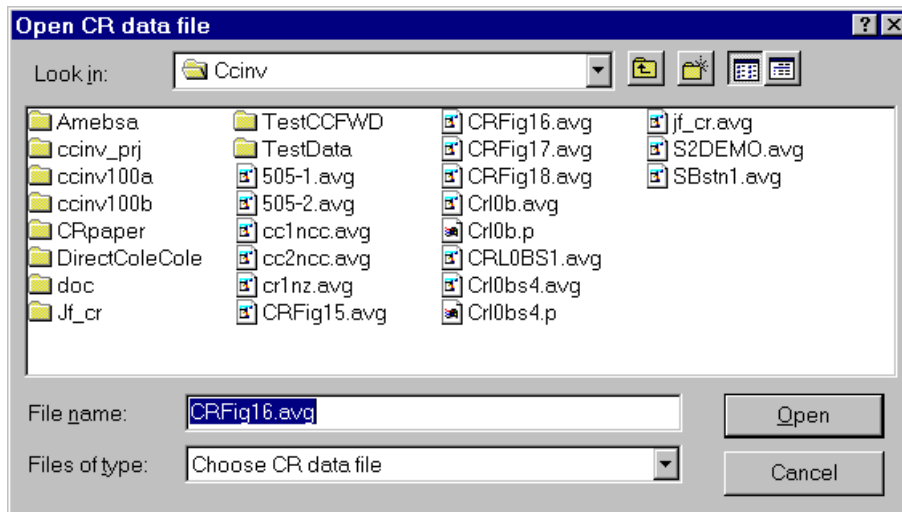
CCINV

CR to Cole-Cole inversion program

Scott MacInnes, 22/May/02

CCINV inverts spectral complex resistivity data to Cole-Cole models with one to three additive Cole-Cole dispersions. CCINV can be started from the MS-DOS command line by typing “CCINV”, from the Start\Run menu by clicking on CCINV.EXE, or via a short cut.

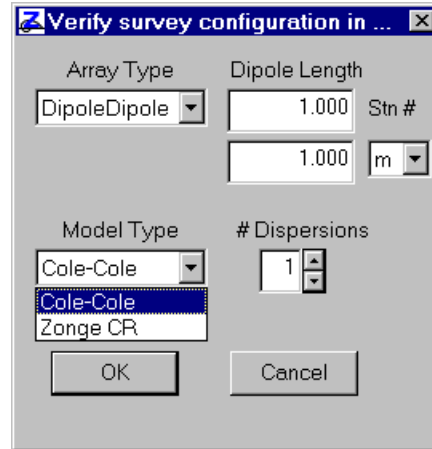
CCINV first shows an open file dialog box.



CCINV reads CRAVG *.avg or GDPHM *.p files to get multi-frequency complex resistivity data for a line of dipole-dipole or pole-dipole data. If inductive coupling is not a concern, then *.avg files are preferred because they include data errors estimated from repeat readings. If inductive coupling is significant, the data decoupled by GDPHM can be read from *.p files. Once an input file is selected, CCINV counts the number of data points, allocates array space and reads the CR data from the input file.

CCINV next looks for an optional *.mde file. If one is not present, it shows an open file dialog box prompting for a *.mde file name. *.mde files provide information about the survey configuration, including possible GDP-to-client station number shifting and scaling. *.mde files are recommended but not required. Mouse click on the Cancel button if you don't need to read station-number scaling from a *.mde file.

Next is a dialog box allowing review of survey configuration and inversion options.



Arrays type options are either Dipole-Dipole or Pole-Dipole. Dipole lengths are shown both in terms of station numbers and length units of m or ft. Station numbers represent distance along line, but may not be scaled to directly indicate length units. CCINV allows inversion to either Cole-Cole (eqn 1) or Zonge (eqn 2) dispersion models. One to three dispersions may be used in the inversion model, although one is usually sufficient, particularly when using the Zonge model. Two Cole-Cole dispersions may be required to fit double peak spectra, but the Zonge model can match double peak spectra with a single dispersion. On rare occasions it may take three Cole-Cole dispersions to fit some spectral curves. Clicking on the Cancel button will drop data input and return you to the main CCINV menu. Click on the OK button to continue to the next step.

Cole – Cole Model

$$\rho_{cr} = R_0 \cdot \left(1 - m \cdot \left(1 - \frac{1}{1 + (j\omega\tau)^c} \right) \right) \quad \text{eqn 1}$$

where

R_0 is d.c.resistivity (ohm - m)

m is chargeability (V/V)

c is frequency dependance (unitless)

Zonge CR model

$$\rho_{cr} = R_0 \cdot \left(1 - \frac{1}{N+1} \cdot \left(1 - \frac{\tanh(\theta)}{\theta} \right) \right) \quad \text{eqn 2}$$

where

$$\theta = \sqrt{\frac{(N+1) \cdot R_0}{2} \cdot \left(\frac{K \cdot q + C_{dl} \cdot q^2 + K \cdot C_{dl} \cdot R_{ct} \cdot q^3}{1 + K \cdot R_{ct} \cdot q} \right)}$$

$$q = \sqrt{j\omega}$$

R_0 is d.c. resistivity (ohm - m)

R_{ct} is charge - transfer resistivity (ohm - m)

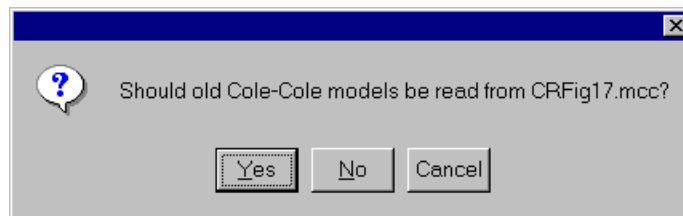
C_{dl} is double - layer capacitativity (farads/m)

K is a Warburg admittivity ($S\sqrt{s}/m$)

N is the ratio of blocked/open pore resistivity (ohm - m/ohm - m)

$\frac{1}{N+1}$ is analogous to m , a chargeability in V/V

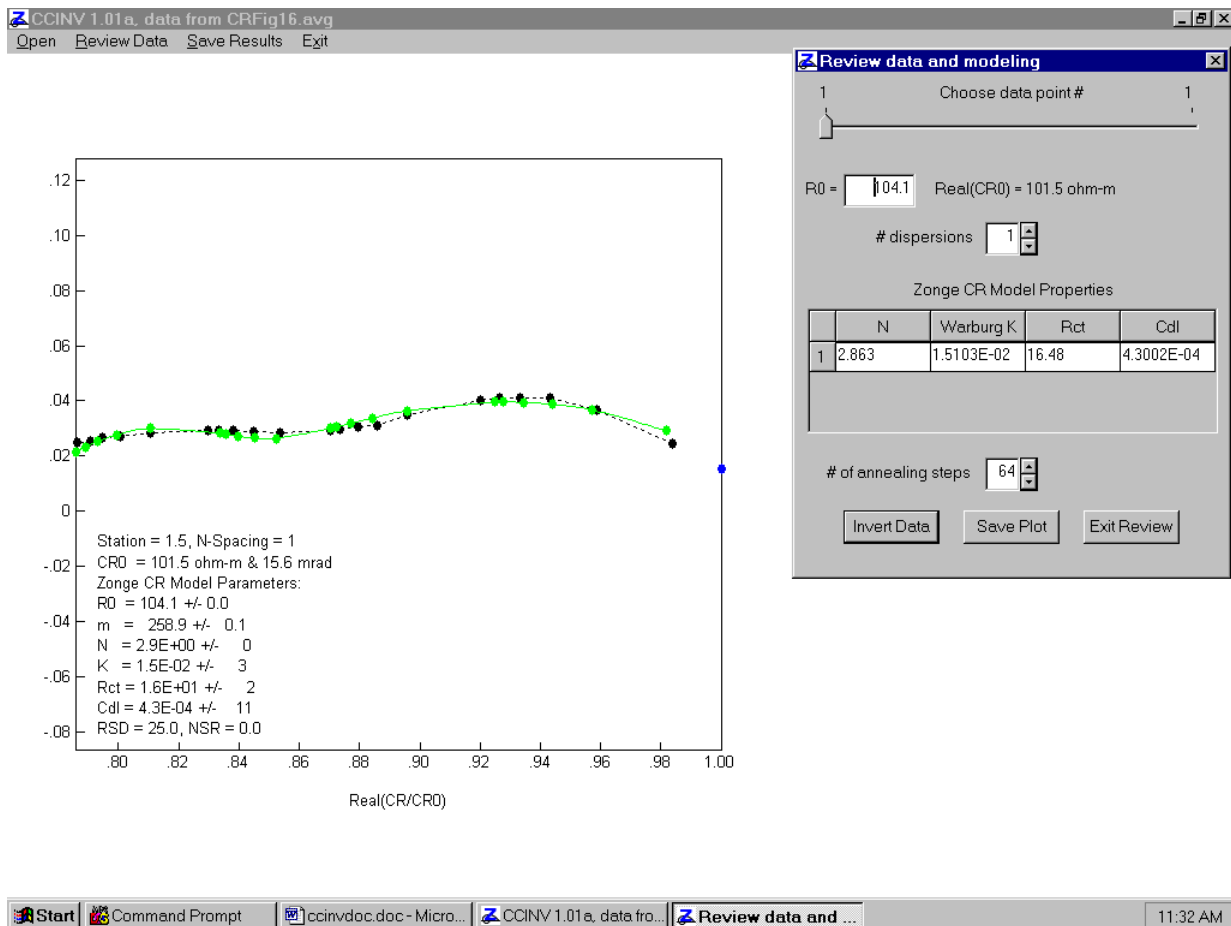
If there is a *.mcc file from a previous run of CCINV in the working directory, CCINV gives you the option of reading existing inversion results from the *.mcc file.



Click on Yes to read existing inversion results, No to re-run all of the inversions using default starting models, or select Cancel to abort data input. If there is no *.mcc file with previous inversion results or if you click on the No button, CCINV works its way through the complex resistivity data set, inverting each data block starting from default model parameters. It shows a complex-plane plot of inversion results as each data block is finished. After all data blocks have been inverted, CCINV saves the results in *.zcc and *.mcc files.

CCINV output *.zcc files are in the Zonge *.z format, suitable for ZPLOT use to produce black and white posted pseudosection plots. *.mcc files have a tabular format suitable for spreadsheet use or contouring by general purpose packages like Golden Software's Surfer.

After inversion, CCINV shows a menu bar with the options **Open**, **Review Data**, **Save Results** and **Exit**. **Open** may be used to select another *.avg or *.p file for inversion. Current inversion results may be reviewed point by point via the **Review Data** option which shows complex-plane plots of Real(CR/CR0) versus -Imag(CR/CR0).

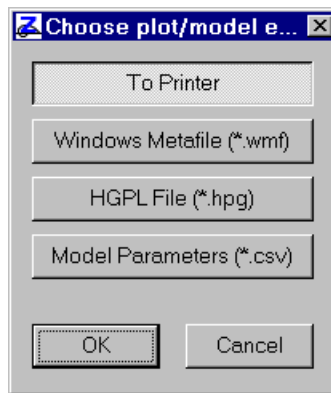


Review Data plots observed complex resistivity data as black circles connected by a dashed line. Vertical and horizontal line segments through each point indicate data error. A value from three-point extrapolation to 0 hertz is shown as a blue dot. Calculated complex resistivity data from the dispersion model are shown as a solid green line with a small circle at each data point. Dispersion model parameters are tabulated in the lower left corner of the plot.

A dialog box on the right side of the screen controls **Review Data**. A track bar across the top of the dialog box allows selection of data blocks for review. Data blocks are left in the order in which they are read from input *.avg or *.p files. After clicking on the track bar pointer with the mouse cursor, you can move back and forth one point at a time with keypad left and right arrow keys.

Dispersion model parameters for the current point can be edited, usually to vary the starting model before rerunning an inversion to attempt an improvement. The number of dispersions in the inversion model can be individually adjusted for each data block. The number of annealing steps controls the amount of extra searching CCINV does during inversion. Using the maximum value of 64 results in a very thorough search for a global minimum. Reducing the number of annealing steps to one limits the inversion to small changes to the current model. Clicking on the **Invert Data** button triggers an inversion of the current data block using the dialog box's starting model and inversion control settings.

Clicking on the **Save Plot** button exports the current complex-plane plot. Plots may be printed, saved as Windows metafiles (*.wmf) or saved as HPGL graphics files (*.hpg). Plot file names are created by appending the current station number and n-spacing to the original input data file name, followed by a file-name extension indicating the file type (.wmf or .hpg). Choosing the Model Parameters (*.csv) button saves a “cloud” of diffusion model solutions for the current station to a csv file. Model parameters in the csv file be used to investigate correlations between model parameters for a group or “cloud” of solutions which all fit the observed CR data fairly well.



Choose the export plot type, then click on the **OK** button to print or save the plot. Clicking on **Cancel** will return you to the **Review Data** dialog box without exporting a plot.

Clicking on the **Exit Review** button in the **Review Data** dialog box returns CCINV to it's main menu, where you can **Open** an new data file, **Review Data** again, **Save Results** in *.zcc and *.mcc files, or **Exit** the CCINV program.

Selecting main-menu option **Save Results**, pops up two choices: **Save to Model-Parameter Files**, which writes model parameters to *.zcc and *.mcc files, and **Save all Review Plots**, which exports all review-data plots for hardcopy without pausing for data review.

*.MCC file format

*.mcc files hold Cole-Cole model parameters in a tabular spreadsheet format with comma-separated columns. Comment lines beginning with a /, \ ! or “ character may be anywhere in the file. *.mcc files may include column-label lines starting with an alphabet character (a to Z, but usually the S in SPlt). CCINV attempts to read all other lines as numeric data.

CCSINV v1.00c expects a fixed column order, with columns of:

SPlt	pseudosection plot point horizontal coordinate (stn #)
ZPlt	pseudosection plot point vertical coordinate (stn #)
NSP	n-spacing
SRx1	receiver electrode location (stn #)
SRx2	receiver electrode location (stn #)
STx1	transmitter electrode location (stn #)
STx2	transmitter electrode location (stn #)
NSR	noise-to-signal ratio = RMS(obs-calc data)/RMS(obs-average) (%)
R0	0 hertz resistivity (ohm-m)
R0err	R0 relative error (%)
NCC	number of dispersions in model (1 to 3)

Cole-Cole model parameters

m	chargeability (mV/V)
Tau	time constant (msec)
C	frequency dependence (unitless)
m_err	chargeability error (mV/V)
Tau_err	time constant relative error (%)
C_err	frequency dependence error (unitless)

Zonge model parameters

N	blocked/unblocked pore resistivity ratio (ohms/ohms)
K	Warburg admittivity (microS $\sqrt{s/m}$)
Rct	charge-transfer resistivity (ohm-m)
Cdl	double-layer capacitance (microfarads/m)
Rct/R0	normalized charge-transfer resistivity (unitless ratio)
N_err	blocked/unblocked ratio relative error (%)
K_err	admittivity relative error (%)
Rct_err	charge-transfer resistivity relative error (%)
Cdl_err	capacitance relative error (%)

There are NCC sets of Cole-Cole model parameter columns. NCC values may vary from line to line within a mcc file, but the NCC value and the number of numeric values on each line should be self-consistent. If a Zonge CR model is used, both Cole-Cole parameters derived from Zonge model values and Zonge model parameters are given.

Cole-Cole chargeability is related to the Zonge diffusion model parameter N: $m = 1/(1+N)$. If Rct and Cdl are very small or 0, then the Cole-Cole parameter tau (with $c = 0.25$) is analogous to the Zonge parameter K: $\tau = ((1+N)*R0*K)^2$. However, in general Rct and Cdl are not small and the Zonge model has more complex behavior at higher frequencies than does the Cole-Cole model. A Zonge model with a single set of parameters can model a double-bump spectra, whereas the Cole-Cole model requires two parameter sets to duplicate a spectra with maxima at two different frequencies.