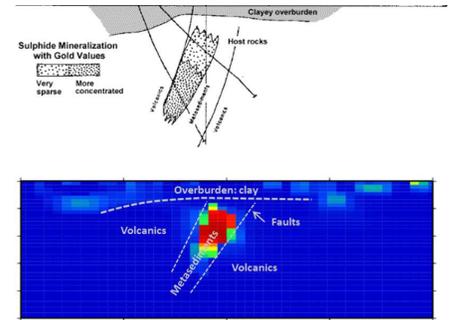# Detailed update summary: DCIP2D v5.0

Geophysical Inversion Facility
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gif.eos.ubc.ca

Overview

`DCIP2D v5.0`: A program library for forward modelling and inversion of direct current and induced polarization data over 2D structures. Significant upgrades reduce computation time through parallelization and increase the flexibility to incorporate geologic information.

Background

UBC-GIF inversions solve the inverse problem by minimizing a global objective function

$$\min \psi = \psi_d + \beta \psi_m$$
$$\text{s.t. } m^l \leq m \leq m^u$$

created from the combination of a data misfit term, ψ_d, and model objective function or regularization term, ψ_m. The regularization is designed so that geological, petrophysical, and geophysical information can be incorporated into the inversion. The trade-off parameter β balances the data fit and model smoothness. Lower (m^l) and upper (m^u) bounds can be specified throughout the model region.
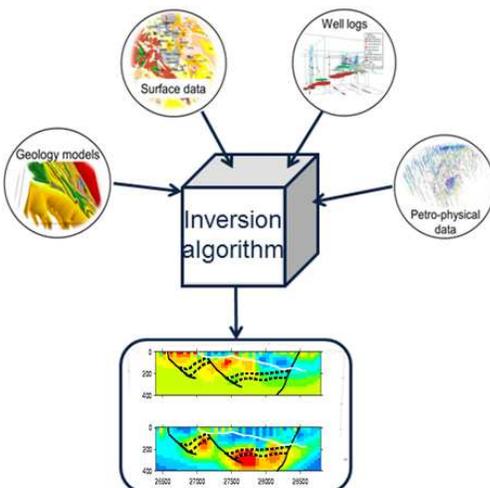
Major improvements

Parallelization

The forward modelling and inversion programs have been parallelized using OpenMP. Computations are distributed over available processors when multiple transmitters are involved. The parallelization is invoked whenever a forward modeling is carried out or when the sensitivity matrix, **J**, is multiplied onto a vector in the Conjugate Gradient (CG) solution. Speedups compared to previous codes will vary based on problem specifics and computer performance.

Electrode locations

Arbitrary locations: Previous versions of the code required electrodes to be on mesh nodes. While convenient for simple arrays and few data, this added complications when working in regions of high topography and with non-uniform surveys such as Schlumberger.

Survey geometry: All linear surface array data, or combinations thereof, can be inverted. For instance Wenner data and pole-dipole data can be inverted simultaneously.

Borehole data: The capability to incorporate borehole data has been added. These data can be inverted individually or in conjunction with surface array data.

Spatially large data sets: Solution of the numerical optimization problem in the previous codes was carried out using a subspace technique. This worked well for typical exploration surveys. However, in some cases where the number of transmitters was very large, the subspace method did not perform adequately. In version 5.0, we overcome this by solving the Gauss-Newton equations using a Conjugate Gradient (CG) method. The CG formulation is the suggested method of solution but the original subspace solution method-

ology, with improvements, is included in version 5.0. This allows users to reproduce results obtained with the older codes. Many of the new features of the codes, for example the Huber and Ekblom norms, bound constraints, active and inactive cells work only with the CG approach.

Incorporating geologic information

An emphasis in version 5.0 is to alter the code to have increased flexibility to incorporate geologic and petrophysical constraints.

Blocky models: A geology represented by blocky models can be constructed by minimizing an l_1 norm of derivative terms in the model objective function. In Version 5.0 the Ekblom norm has been incorporated that lets the user construct models that vary between the usual smooth l_2 norm and the blocky l_1 norm. Further flexibility is provided by having the option of including (or not including) the reference model into various components of the model objective function. The choice of which option depends upon what geologic information is known and its uncertainty.

Bound constraints: Information is incorporated as upper and lower bounds with the projected-gradient method (Vogel, 2002), allowing the recovered model to reach the bounds. This is faster than the interior point methodology used in the subspace method. Bounds can be given on a cell-by-cell basis throughout the model region.

Inactive and active cells: Particular cells, or regions of the model, may be held fixed during the inversion. This reduces the size of the problem and provides an alternative method for incorporating prior information.

Robust misfit norms

Outliers in the data will negatively impact the performance of the inversion algorithm. This can be ameliorated by working with the Huber norm to calculate the data misfit. The Huber norm can range from l_1 to l_2 and is incorporated into DCIP2D.

Sensitivity files and DOI

The average sensitivity for each cell is now written out to a file. This aids the user in understanding the depth of investigation or even in survey design, particularly in areas of high topographic relief (Figure 1). The model and data at each iteration are written for both the DC and IP inversions.
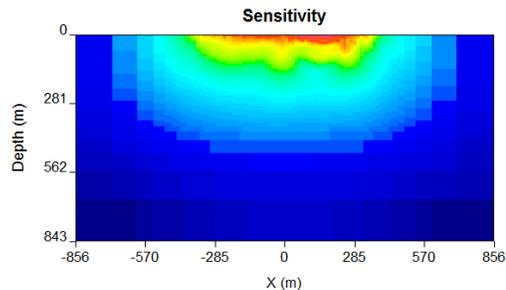

Figure 1: Average sensitivity for each cell for a 2D DC data set.

The forward problem is numerically solved on a large domain but the data are only sensitive to a portion of that volume. Structure appearing at depth and outside the lateral extent of the data array is controlled only by the model objective function and should be removed for final presentation. The useful region of investigation can be estimated within the model viewer GUI using the Depth-of-Investigation (DOI) process from a recovered model or by using the sensitivity. Both options are output from DCIP2D.

Maintenance and future releases

DCIP2D v5.0 is released with a maintenance agreement that includes support for carrying out the inversions as well as receiving upgrades for the software.

Contact information

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