Submission code: 6DXA9WZP7R

See this and other abstracts on our website: https://home.sbgf.org.br/Pages/resumos.php

Automated and Open-Source Routine for Processing and Inversion of Direct Current Resistivity Data

João Paulo Luz Dos Santos Ferreira (Universidade Federal Fluminense (UFF)), Flora Solon (Universidade Federal Fluminense (UFF))

SBGf Conference
18-20 NOV | Rio'25

Automated and Open-Source Routine for Processing and Inversion of Direct Current Resistivity Data

Please, do not insert author names in your submission PDF file.

Abstract Summary

Direct Current (DC) Resistivity is a widely used method in applied geophysics, especially in environmental, geotechnical, and hydrogeological investigations. However, the majority of tools available for processing and inverting DC Resistivity data are commercial, often involving high costs and limited accessibility. These constraints hinder the use of such tools by students and research groups, especially in academic and low-budget contexts.

This work presents the development of a free, automated, and customizable Python based routine that integrates the stages of modeling, processing, inversion, and visualization of eletrical resistivity data. The solution is built upon the open-source *SimPEG (Simulation and Parameter Estimation in Geophysics)* library, which, despite being well documented, still poses technical challenges for beginners.

The proposed routine was tested using both synthetic and real datasets, yielding consistent responses and satisfactory computational performance. This tool demonstrates potential for applications in research, teaching, and outreach, promoting broader accessibility and encouraging the use of geophysical methods in academic environments.

Introduction

The Direct Current (DC) Resistivity method is a well-established applied geophysical method, with recognized utility in environmental, geotechnical and hydrogeological studies. It is widely used to investigate the distribution of electrical resistivity in the subsurface, providing information on variations in lithology, moisture content, and fluid saturation (Loke (2000)).

Although the method is conceptually accessible and widely taught, its practical application is often hindered by the high cost and proprietary nature of most commercial processing and inversion software. These limitations restrict the use of such tools in academic research and educational projects, especially in resource-limited settings.

In response to this scenario, the present work describes the development of a free, automated, and customizable routine, written in Python, that integrates the processing, inversion, and visualization stages of electrical resistivity survey data. However, utilizing these tools still requires a significant level of programming and geophysical expertise. This study addresses this gap by proposing a user-friendly, reproducible, and accessible Python routine that aims to simplify the workflow for DC Resistivity data. By integrating data modeling, processing, inversion, and visualization, the routine facilitates the use of geophysical methods by students, educators, and researchers, thereby contributing to the democratization of applied geophysics.

Method

To develop this routine, we utilized the Python programming language. We built a custom package that leverages functionalities from the *SimPEG (Simulation and Parameter Estimation Geophysics)* library Cockett et al. (2015). *SimPEG* is an open-source framework for geophysical simulation and inversion, designed to be modular and flexible, allowing users to build and customize geophysical modeling workflows. It supports a wide range of geophysical methods, including electromagnetic, seismic, gravity, and magnetic.
Our package integrates *SimPEG*'s core capabilities—specifically focusing on the *"simpeg.electromagnetics.static.resistivity"* functionality for static electrical resistivity simulations and inversions—with our own custom routines for data reading and processing. This bespoke integration was designed to streamline the workflow for understanding the subsurface's electrical properties.
The main steps of our workflow are as follows.

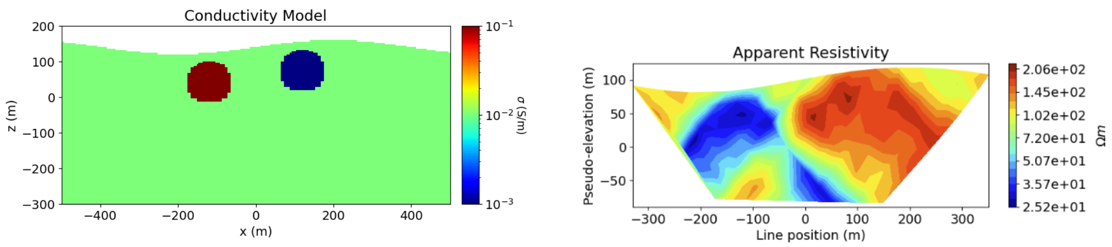
- **Data processing**: Conversion of raw voltage data into apparent resistivity using geometric factors, followed by generation of pseudosections;
- **Survey setup**: Definition of survey geometry and electrode positions, optional integration of topographic data using *"simpeg.maps"* and related utilities;
- **Mesh generation**: Construction of a TreeMesh-type mesh particularly suitable for DC resistivity simulations, using *SimPEG* and *discretize* packages;
- **Model initialization**: Assignment of electrical property values to define a background and possible anomalies;
- **Forward modeling**: Simulation of electric potential using the *"Simulation2DNodal"* class for surface DC resistivity;
- **Inversion**: Definition of data misfit, regularization, and optimization strategies to solve the inverse problem using *SimPEG*'s core modules.

This modular design simplifies the process of applying DC resistivity inversion, particularly for educational and research purposes.

Results

To validate our package routines, we conducted tests using a synthetic model composed of two distinct anomalous bodies—a resistive and a conductive one—positioned beneath an irregular topographic surface, as illustrated in Figure 1a. This configuration was designed to emulate a realistic subsurface scenario and assess the performance of our routines.
Synthetic data were generated using the *SimPEG*-based workflow and subsequently processed and converted to be compatible with the commercial software *ZondRes2D*©, employing its demo model configuration. The observed data pseudossection, shown in Figure 1b, was generated by our custom routine based on *SimPEG*. This enabled a direct comparison between the open source routine and a proprietary inversion platform.
Inversions were performed in both environments with a maximum of 50 iterations. Our *SimPEG*-based routine applied a standard *L2-norm* inversion (Figure 2), while the inversion in *ZondRes2D*© employed the Occam inversion method (Figure 3). In the *SimPEG* framework for DC resistivity inversion, two main strategies are available: the *Weighted Least-Squares (L2)* and the *Iteratively Re-weighted Least-Squares (IRLS)* methods. For this study, we adopted the *L2-norm* inversion,

commonly referred to as the *Occam*(Constable et al. (1987)) inversion, which seeks the smoothest resistivity model that adequately fits the data. This approach is particularly useful when a smooth subsurface structure is expected and the dataset contains low noise. The *Occam* inversion implemented in *SimPEG* closely parallels the *Occam* inversion used in the commercial software *ZondRes2D*©, facilitating a direct comparison between the two platforms. Constable et al. (1987) propose selecting the smoothest possible model that still fits the data adequately, allowing deviations from a simple reference only to the extent required by the observations.



(a) Resistivity model created in SimPEG.

(b) Observed data.

Figure 1: (a) Resistivity model and (b) observed data from the *SimPEG* simulation.

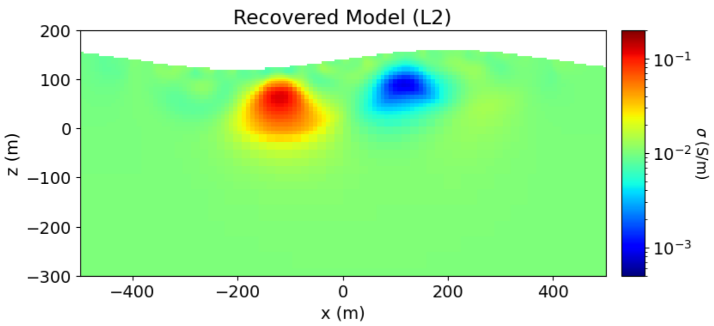


Figure 2: L2 inversion result in *SimPEG*.

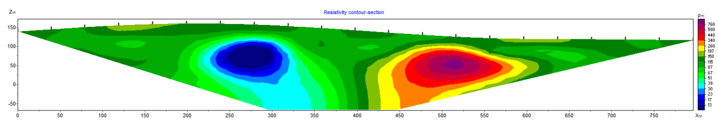


Figure 3: Occam inversion in *ZondRes2D*©.

Conclusions

By analyzing and comparing the models produced through inversions carried out in our custom routines within the *SimPEG*-based package and *ZondRes2D*©, it is possible to conclude that the routine implemented in the proposed workflow demonstrates effective inversion convergence and geophysical consistency in recovered resistivity distributions. The similarities observed in the results from both platforms support the reliability of the custom-built processing and inversion approach.

The tool developed throughout this study emerges as a viable and accessible open source solution for handling Direct Current Resistivity data. Its modular design and integration with a well-established geophysical framework make it particularly suitable for use in academic environments. The routine can be readily adopted in teaching, research, and extension initiatives, especially in settings where the use of proprietary software may be limited due to cost or accessibility.

Future development will focus on expanding the routine's capabilities through the addition of alternative regularization methods, evaluation of more complex geological models, and the implementation of a graphical user interface. These improvements aim to enhance the tool's functionality and usability, particularly for users who are less experienced with coding or numerical modeling frameworks.

References

Cockett, R., S. Kang, L. J. Heagy, A. Pidlisecky, and D. W. Oldenburg, 2015, Simpeg: An open source framework for simulation and gradient based parameter estimation in geophysical applications: Computers & Geosciences.

Constable, S., R. L. Parker, and C. G. Constable, 1987, Occam's inversion: A practical algorithm for generating smooth models from electromagnetic sounding data: Geophysics, **52**, 289–300.

Loke, M., 2000, Electrical imaging surveys for environmental and engineering studies: A practical guide to 2-d and 3-d surveys. (Copyright by Dr. M.H. Loke).