# Time domain mCSEM data in 1-D deep water environments

Diego C. Miranda, Cícero Roberto Teixeira Régis, Federal University of Pará, Brazil



## Abstract

**In this paper, we show how meaningful information can arise from time domain mCSEM data. We modeled mCSEM data from one dimensional environments in the frequency domain and produced time domain data by applying the inverse discrete Fourier transform to those data. Our results show that the presence of a resistive target can be inferred from time domain data in models with water depths up to 2000m.**

## Introduction

The marine controlled-source electromagnetic (also known as Sea Bed Logging - SBL) is a technique that can be used in the detection and characterization of hydrocarbons usually located in deep water reservoirs (Edeismo, Ellingsrud, 2002). It consists of a mobile horizontal electric dipole as a source, carried close to the sea floor wich an array of electromagnetic receivers are deposited properly. The dipole transmitter emits a low frequency signal, that spreads both in the water and in the sediments beneath it and is captured by the receivers. In the receivers, amplitude and phase are recorded which depend on the electrical resistivity of the seafloor.

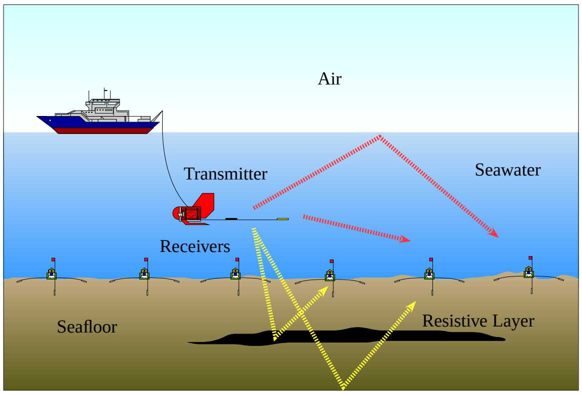


Figure 1: Scheme of a geophysics survey using mCSEM.

Modelling of mCSEM is usually done in frequency-domain since your theoretical formulation. However, time-domain data may provide information on the geophysical of the subsurface equivalent to frequency-domain data (Constable,2007).

Time-domain approaches show up very well adapted in land surveys, where the geological formations are on the conductive side of the air/earth system (Constable, 2007). In marine environments, the system is inversed, and the region of interest becomes the most resistive, i.e., the ocean subsoil, which is more resistive than seawater. So, the information about the seafloor occurs in the early time response while the seawater response dominates late time. This separation of the responses is a very good feature of the time-domain method and cannot be easily observed in frequency-domain. In this paper, we assess the time-domain mCSEM from its frequency-domain results obtained by the 1-d frequency-domain modelling with models that contain or not the resistive layer which represents the hydrocarbon reservoir.

We have considered two kinds of current distribution in the sources: the impulse and the step function. Our results show that information about the presence of the resistive layer can be inferred from both those forms of source current

## Method

For the 1-D problem, we use the formulation based on the decomposition of the primary signal in flat waves and the Schelkunof Potentials to obtain the electric field in the receivers. (Ward and Hohmann,1988). We start from Maxwell´s Equations in the frequency domain, obtaining values that represent the radial electric field. To calibrate our program, we approximated the mCSEM geoelectrical model for a homogeneous formation and compared the results with the exact solution of this problem, which can be found in, for instance, Ward and Hohmann (1988). Figure 2 shows the exact and numerical frequency-domain solutions for the normalized $E_x$ measured by a single receiver in a homogeneous formation with resistivity of $\rho = 1\ \Omega$m and distance of 900 m from the transmitter.

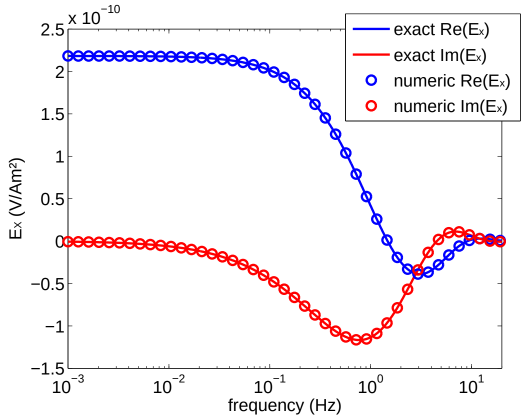


Figure 2: Real (blue) and imaginary (red) part of $E_x$ for various frequencies.

To obtain the time-domain solution, we needed to perform the discrete Fourier Transform and this implies in calculating the responses for a large number of frequencies. Naturally, the use of such a number of frequencies increases the computational time of the task. For a 1-D model this is not necessarily an issue, but for 2-D and 3-D models, it can be a very demanding problem. To address this problem, we also adapted our code to run in parallel machines. We have used the parallel environment provided by the Netuno cluster, located at the Federal University of Rio de Janeiro. Thus, the task could be divided (we distributed the calculations for various frequencies among the Netuno´s execution nodes), decreasing the total execution time. Working with parallel computing will be our best choice when we apply our code to 2-D models in our next research phase.

## Results

We use the model presented by Constable and Weiss (2006) showed in figure 3. It has a hydrocarbon reservoir with a resistivity of 100Ωm and thickness of 100m, buried at a depth of 1000m between sediments of resistivity of 1Ωm. The sea has resistivity of 0.3Ωm and depth of 1000m.

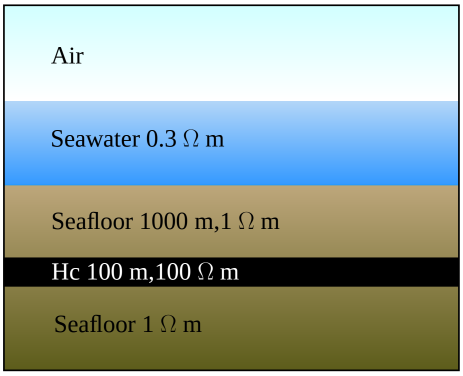


Figure 3: 1-D geoelectrical model.

The results below are the time-domain solution obtained by discrete Fourier transform of the frequency-domain data. We study two different functions representing the current in the source: an impulse function, representing a sudden increase and decrease in the current in a very short time and a step function, representing a current that is turned suddenly on and remains steady for a long time.

Figures 4 and 5 display the impulse response for a source at the origin and receivers located at 2000m and 5000m respectively, considering sea depths of 500m, 1000m and 2000m in wich of them.

Although a simple separation of the airwave response in our data is not possible due to the complex coupling between the air interaction and seafloor signals (Andréis and Macgregor, 2007), we can clearly note part of this influence when the sea depth is enlarged in the impulse graphs. As the sea depth is increased, the peak of the air wave influence is shifted farther from the source.

Figures 6 and 8 display the step response for receivers located at 2000m and 5000m from the source, respectively, considering sea depths of 500m, 1000m and 2000m. Figures 7 and 9 display the same HC data normalized by the corresponding noHC response.

In the normalized curves we have a measure of the relative influence of the resistive layer on the data. The lower peak in the 2km offset shows a strong influence of the field directly from the source, which is greater than the influence of the resistive layer as well as of the air-water interface. When the offset is 5km the peaks are higher than before, which shows that the resistive layer is felt more strongly, while the direct field from the source is relatively weaker. Also, note that the influence of the air-water interface is increased, since now the curves for the depths of 1000m and 2000m are clearly separated, which was not the case in the 2km offset.

## Conclusion

The results show that meaningful information about the geoelectrical structure under the sea can be inferred from time-domain mCSEM data, even in deep water. In the sequence of this research, we will investigate the information that can be gathered from 2D and 3D models, by formulating the problem in the time domain from scratch.

## References

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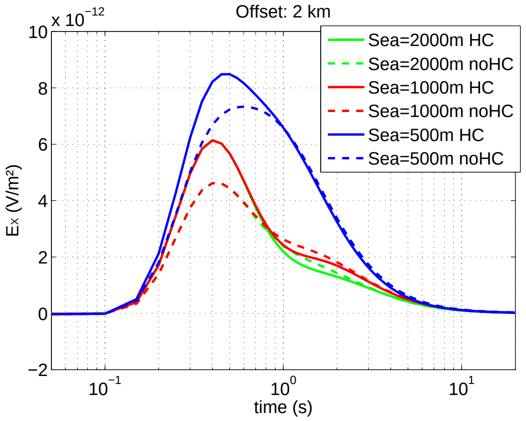


Figure 4: Time-domain solution for the impulse response at a source-receiver distance of 2000 m for various sea depths.

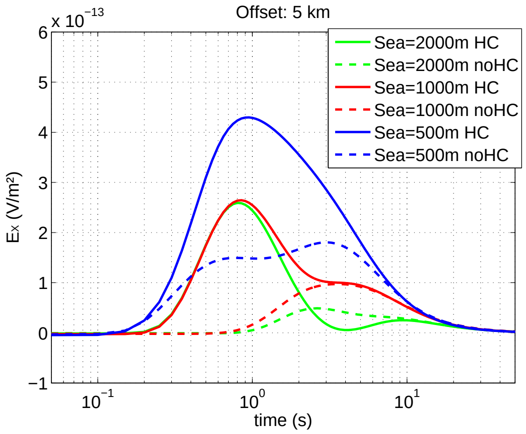


Figure 5: Time-domain solution for the impulse response at a source-receiver distance of 5000 m for various sea depths.

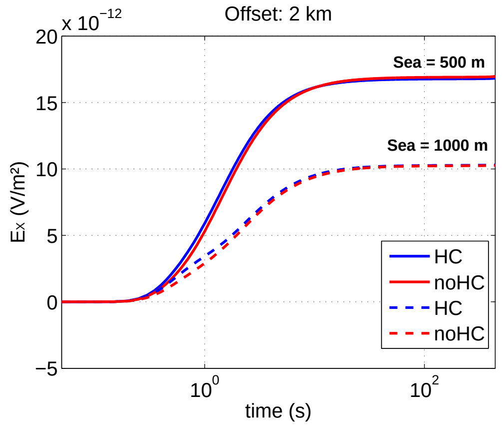


Figure 6: Time-domain solution for the step response at a source-receiver distance of 2000 m.

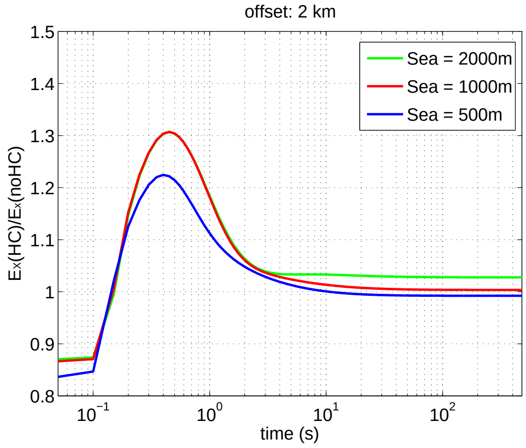


Figure 7: Normalized solution for the step response at a source-receiver distance of 2000 m.

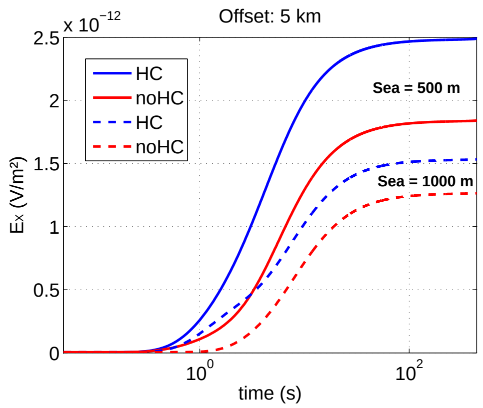


Figure 8: Time-domain solution for the step response at a source-receiver distance of 5000 m.

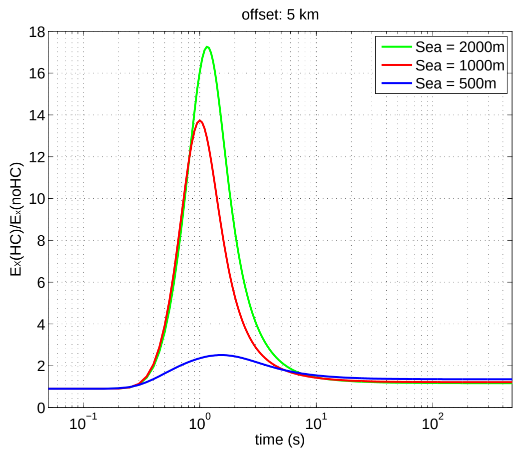


Figure 9: Normalized solution for the step response at a source-receiver distance of 5000 m.