Master thesis projects: *Maxwell equations: Reversed*

Background: In physics we often learn how to calculate the electric and magnetic field (**d**) using the Maxwell equations (**G**) given the properties of a medium (**m**), the so-called forward problem. In real life, the situation is typically reversed. We perform measurements of the electric and magnetic field data and use the Maxwell equations, in the reversed sense, to deduce the medium properties, the so-called inverse problem.

$$\boldsymbol{d} = \boldsymbol{G}\boldsymbol{m} \qquad \text{forward problem}$$

$$\boldsymbol{m} = \boldsymbol{G}^{-1}\boldsymbol{d} \qquad \text{inverse problem}$$

(Un)fortunately **G** is almost never invertible in real life and one has to make a large number of assumptions and approximations to be able to solve for **m** given **d** and **G**.

Controlled-Source electromagnetic (EM) method is a new and growing remote sensing technology. Here, one acquires the electric and magnetic fields at the surface and tries to invert for the resistivity in the sub-surface.

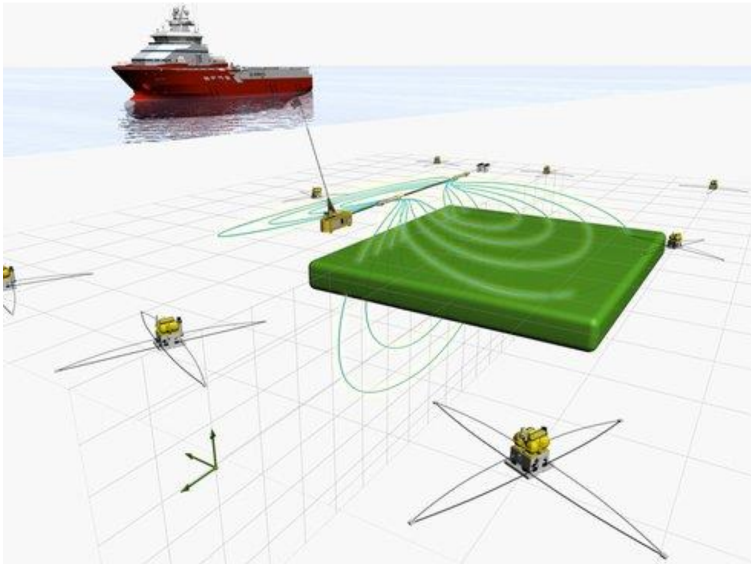

Figure 1: Sketch of the controlled-source electromagnetic method, http://www.emgs.com/image_library/method_illustrations/?offset=6

The EM R&D group in Statoil's research center in Trondheim is one of the world leading groups in incorporating other geophysical information into the EM inversion problem to construct 3D sub-surface resistivity models with higher resolutions than standard EM inversions.

Objectives: We need two motivated students to test out new ideas for improved inversion. In more details:

Project 1: Full covariance matrix EM inversion

Let **d**=[d_1, d_2...d_N] be the data vector of N measured data points. We then search for a model **m** that minimizes the following misfit functional

$$\boldsymbol{\varepsilon}(\boldsymbol{m}) = \sum_{\boldsymbol{i}=\boldsymbol{1}..\boldsymbol{N}} (\boldsymbol{d_i} - \boldsymbol{d_i^s})^* \boldsymbol{C}^{-\boldsymbol{1}} (\boldsymbol{d_i} - \boldsymbol{d_i^s})$$

where the synthetic data are created using the forward operator $\mathbf{d}_i^s=\mathbf{Gm}$. Here, **C** is the covariance matrix providing the uncertainties of the measured data points. Presently, **C** is assumed diagonal i.e. the uncertainties of the data points are uncorrelated. This is not the case in EM measurements. The project seeks to study the effect of a non-diagonal covariance matrix in EM inversions.

Project 2: Comparison of several EM inversion algorithms

Inversion is typically done iteratively. At each iteration, one needs to solve a large system of linear equations called the normal equations. Several algorithms exist, with respective advantages and disadvantages in terms of computing time, memory requirements, stability, convergence, etc. Typical algorithms include the Gauss-Newton method, quasi-Newton methods (e.g. BFGS or LBFGS), the Levenberg-Marquardt algorithm and the OCCAM algorithm. There has never been done a thorough comparison of the different algorithms, and of their relative strengths and weaknesses. The project seeks to do exactly that using EM data.

Student requirements: Skilled students in physics and mathematics.

Working place: Statoil's research center at Rotvoll, at least partly.

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