Abstract

Inversion and Depth Range of Dipole Electromagnetic Induction Measurements in Geophysics

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Electromagnetic induction geophysical methods are, basically, composed by a transmitter which produces a magnetic field and a set of receivers which measure the primary magnetic field, from the transmitter, superimposed by secondary magnetic fields inducted in the subsurface. Equipment operating at, relatively, low frequencies and with short distances between the transmitter and the receivers are usually called conductivity meters and operate at low inductions numbers. The depth of investigation, in such kind of equipment, depends mainly on the transmitter-receiver distance, on the orientations of the magnetic dipoles and the height of the instrument from the ground, in order that a depth sounding can be done changing these parameters in a single measurement location. Making a series of these multi-configuration measurements, two-dimensional, or even three-dimensional surveys, can be performed and, subsequently, inverted in order to produce an image of the subsurface of the earth.

Forward modelling and inversion of multi-configuration electromagnetic induction data can be made using the full non-linear solution of Maxwell's equations or using the linear low induction number approximation. Here, the errors observed when using this linear approximation are studied in order to check its validity and is introduced a methodology to overcome these errors in order to obtain more reliable values of the apparent conductivity. Forward modelling using the low induction number approximation makes use of the cumulative response functions, which were originally designed for instruments operating at the surface of the earth. Here, new analytical relative and cumulative response functions are introduced, taking into account the height of the equipment from the ground. The influence of this height upon the depth of investigation is analytically studied. Here is also presented a study of the validity of the low induction number approximation.

Inversion of geophysical data is one of the greatest problems in applied geophysics, as the number of subsurface unknown parameters is much greater than the number of observed data. Besides that, the data is contaminated by noise and thus the inverse problem may have a huge number of solutions which would lead to a good fit between observed and modelled data. In electric and electromagnetic methods, the non-uniqueness of the solution can be caused, for example, by the principle of equivalence in one-dimensional earth models, which is discussed thoroughly here. Special focus is given to the difference in the order of magnitude of this problem when using, as observed data, the apparent conductivity or the real and imaginary parts of the electromagnetic field.

Here is introduced a quasi-two-dimensional, which could also be extrapolated to three-dimensional, inversion procedure. The basic procedure is to find the point of the electromagnetic survey which is more likely to be within an one-dimensional environment; estimate an initial one-dimensional model, for the chosen point of the survey, using a linear inversion approach using the Moore-Penrose pseudo-inverse; use the non-linear variable metrics method to solve the damped least square inverse problem where the previously obtained initial one-dimensional is used as *a priori* information to obtain a more realistic one-dimensional model for the initially chosen point, as it is obtained from the full

solution of Maxwell's equation; use the previously obtained one-dimensional inverted model as *a priori* information to the neighbour points and these newly obtained inversions are used as *a priori* information for their next neighbours and so on.

Finally, the introduced inversion procedure was tested for several two-dimensional synthetic and real data. The inversions results were compared with the inversion of electrical resistivity tomography data collected at the same sections. A discussion about the differences found between these two inversions, by the means of comparisons using synthetic and real data, is presented. The electric field shielding problem, where great differences between the two inversions are particularly observed, is studied by means of a synthetic example.