GENERAL FORMALISM FOR THE EFFICIENT CALCULATING THE DERIVATIVES OF EM FREQUENCY-DOMAIN RESPONSES AND THE DERIVATIVES OF THE MISFIT

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Electromagnetic (EM) studies of the conducting Earth, from the near surface to regional and global, have advanced significantly over the past few years. This progress was driven, in particular, by the increased accuracy, coverage and variety of the newly available data sets, as well as by the new developments in the methods of three-dimensional (3-D) modeling and 3-D inversion of EM data. Due to the large scale of the 3-D inverse problems the iterative gradient-type methods have been mostly using. These methods rely on the calculation, at each iteration, of the gradient of the misfit function with respect to the model parameters. However, even with the modern computational capabilities the straightforward calculation of the gradients based on numerical differentiation is forbidden due to its tremendous computational loads. Much more efficient and elegant way to calculate the misfit gradient is provided by so-called “adjoint” approach which is now widely used in many 3-D numerical schemes for inverting EM data of different types and origin. This approach allows for calculating the misfit gradient for the price of only a few additional forward calculations. In spite of the growing popularity of the approach we did not find in the literature its comprehensive and general description which would allow the researchers to apply the adjoint methodology for their settings straightforwardly. In this work we fill this gap and present general formalism to calculate sensitivities (derivatives) of the response functions and gradient of misfit with respect to variation of conductivity (whether isotropic or anisotropic). Using this formalism one can readily obtain appropriate formulae for the specific sounding methods. We provide such formulae for a number of EM techniques, namely: geomagnetic depth sounding (GDS), horizontal gradient sounding (HGS), new sounding method that combines HGS with GDS, conventional magnetotelluric method and generalized magnetotelluric method. We also show how the developed formalism is adapted for inversion of magnetovariational tippers, as well as inversion of multi-site transfer functions—horizontal magnetic and electric tensors.

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