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Magnetotelluric Inversion for 2-D Anisotropic Conductivity

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Inversion of electromagnetic induction data for electrical conductivity with arbitrary anisotropy still presents a problem due to intricate relations between the anisotropy parameters within the structure under study. In 1-D case, combinations of anisotropy parameters are known which are unresolvable, in the exact sense, by magnetotelluric soundings. In higher dimensions, those parameters are mostly not irresolvable exactly, but they often turn into strongly correlated parameter groups, with possibly only locally enhanced resolvability over anomalous zones where strong lateral gradients of the conductivity and/or anisotropy occur.

We report on the state of the art in the development of a non-linear conjugate gradient (NLCG) version of the 2-D inverse algorithm for magnetotelluric data over structures with arbitrary electrical anisotropy. The algorithm is based on the Occam inverse strategy. As a direct solver, our 2-D finite volume forward modeling program for structures with arbitrary anisotropy is employed, which is also further used for effective evaluations of the parametric sensitivities by utilizing the reciprocity principle. A standard Polak-Ribiere NLCG algorithm is then applied to minimize the inversion objective function which consists of a data misfit term and of regularization penalties applied to both the structure complexity and anisotropy throughout the model. The algorithm offers considerable savings to the computing time and memory demands due to both the reciprocity-based evaluation of the parametric sensitivities and on-line computation of products of the Jacobian and its transverse with a vector within the CG algorithm. A series of post-processing steps is implemented in order to assess the significance, uniqueness and resolution of the anisotropy parameters in the inverse model.

We present several synthetic tests of the 2-D anisotropic inversion for simple block models with different anisotropic features which can sometimes generate magnetotelluric data with highly anomalous characteristics. In particular, models with strong near-surface azimuthal anisotropy can produce anomalous magnetotelluric phases travelling across quadrants for periods below the static shift approximation limit. This kind of distortion largely masks the deeper regional structure, though the distortion pattern itself is affected by the regional condutors.

The 2-D anisotropic inversion is further applied to experimental data of the BC87 data set suggested previously for a detailed analysis at special MT Data Interpretation Workshops in the 1990s. The inverse experiment is focused on a subsection of a profile traversing a batholith structure where a uniform pattern of out-of-quadrant MT phases is observed over a distance of more than 50 km, and large electrical macro-anisotropy was discussed already earlier as a possible causative factor in this regard. The inverse 2-D model fits the complete impedance tensor data satisfactorily at a number of the sites involved, although a few sites could not be fit properly. The inverse model suggests an anisotropic domain within the batholith body with more than one order-of-magnitude resistivity contrast and varying anisotropy strike. Dependence of the inverse results on a pre-selected structural strike is examined. Comparison of the distribution of parameters of the electrical anisotropy with earlier interpretations is attempted.