Three-dimensional natural electromagnetic field inversion with topographic effects

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Resource prospecting in regions of young orogenesis such as the western Americas must contend frequently with steep terrane* underlain by variable rock masses. For the electromagnetic (EM) methods generally, and magnetotellurics (MT) in particular, several factors influence data character and numerical interpretation for such environments. The first is the added variation of receiver level relative to the subsurface target location, which can be viewed as a distortion of the flat-earth version of target response. The second is the response of the topography per se, where MT soundings located on elevations tend to experience a relative depression of the electric field and hence impedance, while soundings in depressions tend to exhibit inflation of the E field. The third factor is the accuracy with which a numerical MT inversion algorithm will simulate the presence of significantly variable slope with which the MT soundings are in contact. Issues here pertain to numerical mesh character such as smoothness of surface and proper high frequency asymptotes. Finite elements appear to have an advantage in this regard of accuracy relative to standard finite differences due to more conformable surfaces.

We describe workings and results of a computer algorithm based upon deformable hexahedral finite elements solving the electric field for 3D inversion of natural EM field responses including substantial topographic variations. Direct matrix solutions are used throughout, including the finite element system matrix, the jacobians and the Gauss-Newton parameter step matrix. The last step is achieved by transforming to data-space. Earth models utilizing about one million parameters can be computed on single-box, large-RAM, multi-core workstations suitable for parallelization of the direct matrix solvers. This is a different computer architecture from the distributed cluster systems typically used to invert data with algorithms invoking iterative solvers. Also investigated is the augmentation of ground MT data by airborne natural field data such as ZTEM™ . Specifically, the possibility of gaining well resolved earth models using only sparse ground MT data with dense airborne coverage is tested numerically and with field data. We will present 2D and 3D examples from mining and volcanic environments illustrating the advantages of rigorous terrain* simulation.

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