Dimensionally Adaptive Simulation and Inversion of Magnetotelluric Measurements

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The magnetotelluric (MT) method is an exploration technique that employs electromagnetic waves. It aims at estimating the resistivity distribution, and therefore at providing an *image* of the subsurface addressing scales varying from few meters to hundred of kilometers [1]. MT measurements are described by Maxwell's equations with a surface source located at the ionosphere.

To simulate MT measurements, we reduce the computational cost of solving the direct problem by solving for the secondary field formulation instead of the full formulation. To decrease the computational costs required to perform the inversion, we design an adaptive multi-dimensional inversion algorithm, which consists of increasing step by step the dimension in which the direct and inverse problems are solved. First, we compute the primary field with an analytical solution and we invert the problem. After that, we introduce higher dimensional heterogeneities and we perform the inversion employing the solution to the previous inverse problem as a regularization term, increasing the robustness of the inversion algorithm.

To illustrate the method, in this work we assume a subsurface resistivity distribution that consists of a one dimensional (1D) contribution plus some two dimensional (2D) inhomogeneities. Then, we split the electromagnetic fields into their primary and secondary components, the former corresponding to the 1D contribution, and the later to the 2D inhomogeneities. While the primary field is solved via an analytical solution, for the secondary field we employ a multi-goal oriented self-adaptive *hp*-FEM [2] with a Perfectly Matched Layer to truncate the computational domain. From these solutions, we obtain the impedance and/or the apparent resistivity, two suitable physical magnitudes to perform the inversion. The inverse problem is solved with a L-BFGS-U gradient based method.

References

[1] K. Vozoff, Magnetotellurics: Principles and practice. *Journal of Earth System Science*, Vol. **99**, 441–471, 1990.

[2] D.Pardo. Multigoal-oriented adaptivity for hp-finite element methods. *Procedia Computer Science*, Vol. **1**, 1953–1961, Elsevier 2010.