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An efficient algebraic multi-resolution sampling approach to 3-D magnetotelluric modelling

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Since electromagnetic (EM) fields diffuse more smoothly to greater depth, it physically makes sense to apply fine discretization to model structure at near surface with an increasingly coarser grid both in horizontal and vertical directions as the depth increases for the numerical solution of EM fields. For finite-difference magnetotelluric (MT) forward modelling on regular staggered grids, this can lead to difficulties in discretizing the curl – curl equation governing the EM diffusion in the earth at regions, where the grid resolution changes. In this paper, we propose an efficient algebraic multi-resolution sampling (MRS) method for MT forward modelling. In this method, we do not require the generation of physical subgrids and merely subsample the field components. The coefficient matrix for the subsampled components can be obtained by matrix multiplication based on the initial linear system of equations and field interpolation. To guarantee divergence-free current during the iterative solution process at low frequencies, which is considered crucial for the development of ef ficient iterati v e solv ers, our forward modelling is based a regularization equation obtained by augmenting the curl – curl equation with an equi v alent scaled grad – div operator for electrical fields (explicitly enforcing the divergence-free condition). The correctness of our algebraic MRS algorithm is examined based on a layered model. Its stability and efficiency is exploited by comparing our results with the forward modelling on unsampled staggered grids for the Dublin Test Model 1 (DTM1) and a complex model with realistic topography, indicating a time reduction of about 42 – 82 percent.