Hybrid GPU solution to regularized divergence-free curl-curl equations for electromagnetic inversion problems

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SUMMARY

The Curl-Curl equation is the key to the time-harmonic electromagnetic (EM) problems in geophysics. The efficiency of its solution is decisive to the performance of EM simulations, which account for over 90% of the computation cost in inversions like Magnetotellurics or controlled source EM problems. However, most published EM computation codes are still CPU-based and cannot utilize the recent computation techniques with GPUs. Based on the previously proposed divergence-free algorithm developed on CPUs, this study demonstrates the current limits of the CPU-based inversion procedure. To exploit the high throughput computational ability of GPUs, the study proposes a hybrid CPU-GPU framework to solve the forward and adjoint problems of the EM inversions. The large sparse linear systems arise from the staggered-grid finite difference approximation of curl-curl problems are solved with a new mixed-precision Krylov subspace solver. The algorithm is implemented with the ModEM modular inversion package and with both synthetic and real-world magnetotelluric examples. The results show a promising 15-30x speed-up for the solution stage of the curl-curl equations over single-CPU calculations. On real-world inversion test cases, the overall performance of a GPU-attached computation node with the new hybrid framework is comparable to that of four CPU-only nodes with conventional ModEM implementation. This would make the large-scale frequency domain EM inversions possible on smaller modern GPU platforms with reduced carbon footprint.

Keywords: divergence-free, curl-curl equation, GPU, magnetotellurics, inversion