**An extended hybrid OCCAM-CG algorithm with application to inversion of mCSEM data**

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# Abstract

We have developed an extended hybrid Data Space OCCAM-Conjugate Gradient (mtxOCCAM-DCG) algorithm suitable for the nonlinear 3D inversion of multi-transmitter/frequency mCSEM data. It combines the memory and time efficiency of using Conjugate Gradient to solve the linear system of normal equations in a Gauss-Newton inversion, with the automatic selection of regularization/step length parameters as in the OCCAM algorithm. The basic hybrid algorithm (OCCAM-DCG) is based on the Golub-Kahan bidiagonalization of the Jacobian matrix followed by solution of the projected Gauss-Newton normal equations in a lower dimensional Krylov subspace. This reduction in problem dimension makes the OCCAM scheme computationally practical even for the large-scale inversion problems that we are interested in. In the new algorithm, mtxOCCAM-DCG, we save computations from the multiplicity of transmitter positions and frequencies to augment the dimension of the underlying subspace in which the Jacobian matrix is projected; this speeds up the convergence of the iterative solution of the normal equations during the Gauss-newton update, reducing the number of iterations, total computational time and memory usage relative to the OCCAM-DCG scheme. We show the effectiveness of our method through the inversion of a synthetic datasets based on the Marlim 3D resistivity model, demonstrating a significant speed up in convergence rate in comparison to OCCAM-DCG, and to a standard implementation of a Nonlinear Conjugate Gradient algorithm. We also demonstrate how the proposed algorithm can be useful in a joint inversion scenario, in our case combining MT and mCSEM data. The hybrid scheme allows for efficient exploration of relative weights for the different measured data types. Besides, model sensitivities are automatically generated during the iterations of the algorithm; this information can be used in a posterior stage of the inversion for approximate uncertainty and resolution analysis of the solutions obtained.