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3D voxel imaging of subsurface magnetic permeability / susceptibility with loop-loop frequency domain electromagnetic induction sensors

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The in-phase response collected by portable loop-loop electromagnetic induction (EMI) sensors operating at low and moderate induction numbers is typically used for sensing the magnetic permeability (or susceptibility) of the subsurface because it contains a rather small "induction" fraction depending on the electrical conductivity. The magnetization fraction of the in-phase signal, which is sensitive to the surrounding magnetic permeability, follows the magneto-static equations similarly to the magnetic method but with an active magnetic source. The use of an active source offers the possibility to collect data with several loop-loop configurations, which illuminate the subsurface with different sensitivity patterns (Klose *et al*., 2018). Such multi-configuration soundings thereby open the door to the imaging of subsurface magnetic permeability/susceptibility variations by an inversion procedure. Such an imaging procedure, which focuses on the induced magnetization effect, overcomes the classical depth ambiguity generally encountered with passive geomagnetic data.
To invert multi-configuration in-phase data sets, we apply the 3D full-grid multi-channel deconvolution (MCD) procedure presented in Guillemoteau *et al*. (2017). This fast imaging algorithm allows us to invert large in-phase data sets (e.g., consisting of more than a hundred thousand data points) for a dense voxel-based 3D model of magnetic permeability subject to smoothness constraints. In this study, we first present and discuss synthetic examples of our inversion strategy, which aim at simulating realistic conditions. Finally, we demonstrate the applicability of our method to field data collected across an archaeological site in Auvergne (France) to image the foundations of a gallo-roman villa consisting of basaltic rock material. Our synthetic and field data examples demonstrate the potential of the proposed inversion procedure offering new and complementary ways to interpret data sets collected with modern EMI instruments.

References:

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