A novel joint inversion approach for electrical resistivity tomography and sparse transient electromagnetic data

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SUMMARY

Different geophysical prospecting techniques have specific advantages and disadvantages. Depending on the method, they are sensitive to different physical parameters, such as the electrical resistivity or density. But also methods that resolve the same physical parameter, may have different sensitivity and resolution characteristics, due to the specific source-receiver configuration for example. Similarly, the investigation depths can differ. To provide an improved subsurface image, measurements from different methods can be efficiently combined in a joint inversion process.

Here we present a novel joint inversion based on the framework pyGIMLi. We combine the loop source Transient Electromagnetic Method (TEM) and Electrical Resistivity Tomography (ERT) in a hybrid quasi 2D joint inversion scheme. ERT is commonly collected in a 2D manner and has a superior lateral resolution, whereas TEM provides a much larger depth of investigation and has a superior layer resolution, particularly for conductors. However, TEM is usually collected comparably sparse and the multi-dimensional inversion is extremely challenging. In the past, various 1D TEM and Vertical Electrical Sounding joint inversion approaches were presented. For weak 2D problems, more sophisticated quasi-2D approaches using for example laterally constrained inversion can be efficiently applied. However, until now there is no development that combines 2D ERT with 1D TEM in an inversion scheme.

Our developed 2D-1D hybrid joint inversion approach is capable of integrating 2D ERT data and TEM soundings along a profile line, using a fast semi-analytic 1D TEM forward operator. The model is parameterized in 2D using quadrilaterals. For TEM, model columns are extracted below each sounding. A pseudo 2D TEM Jacobian is constructed and combined with the full 2D ERT Jacobian. To compensate for weak 2D effects and to include neighboring cells in the TEM response, a depth-dependent weighting function is used for material averaging. This also allows for an approximated 2D sensitivity calculation by laterally distributing the sensitivities across cells. This approach allows a smoothness constraint inversion, readily implemented in the pyGIMLi inversion toolbox. The cost-function is minimized incorporating a data term plus a 2D smoothness constraint using a step-wise cooling for the regularization parameter.

Systematic synthetic modeling studies are carried out to evaluate the performance and limitations of the proposed method. Our synthetics and field data studies demonstrate that the approach is applicable to both single pseudo 2D TEM inversion as well as 2D hybrid joint inversion.

Keywords: Joint Inversion, Transient Electromagnetics, Electrical Resistivity tomography