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Geostatistical FDEM inversion: a three-dimensional real case application

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The near surface is a complex and often highly heterogeneous system as its current status results from interacting processes of both natural and anthropogenic origin. Effective sustainable management and land use planning, especially in urban environments, demands high-resolution subsurface property models enabling to capture small-scale processes of interest. The modelling methods based only on discrete direct observations from conventional invasive sampling techniques have limitations with respect to capturing the spatial variability of these systems. Near-surface geophysical surveys are emerging as powerful techniques to provide indirect measurements of subsurface properties. Their integration with direct observations has the potential for better predicting the spatial distribution of the subsurface physical properties of interest and capture the heterogeneities of the near-surface systems.

Within the most common geophysical techniques, frequency-domain electromagnetic (FDEM) induction methods have demonstrated their potential and efficiency to characterize heterogeneous deposits due to their simultaneous sensitivity to electrical conductivity (EC) and magnetic susceptibility (MS). The inverse modelling of FDEM data based on geostatistical techniques allows to go beyond conventional analyses of FDEM data. This geostatistical FDEM inversion method uses stochastic sequential simulation and co-simulation to perturbate the model parameter space and the corresponding FDEM forward model solutions, including both the synthetic FDEM responses and their sensitivity to changes on the physical properties of interest. A stochastic optimization driven by the misfit between true and synthetic FDEM data is applied to iterative towards a final subsurface model. This method not only improve the confidence of the obtained EC and MS inverted models but also allows to quantify the uncertainty related to them. Furthermore, taking into account spatial correlations enables more accurate prediction of the spatial distribution of subsurface properties and a more realistic reconstruction of small-scale spatial variations, even when considering highly heterogeneous near surface systems. Moreover, a main advantage of this iterative geostatistical FDEM inversion method is its ability to flexibly integrate data with different resolution in the same framework.

In this work, we apply this iterative geostatistical FDEM inversion technique, which has already been successfully demonstrated for one- and two-dimensional applications, to invert a real case FDEM data set in three dimensions. The FDEM survey data set was collected on a site located near

Knowlton (Dorset, UK), which is geologically characterized by Cretaceous chalk overlain by Quaternary siliciclastic sand deposits. The subsurface at the site is known to contain several archaeological features, which produces strong local in-phase anomalies in the FDEM survey data. We discuss the particular challenges involved in the three-dimensional application of the inversion method to a real case data set and compare our results against previously obtained ones for one- and two-dimensional approximations.