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Geostatistical inversion of electromagnetic induction data for landfill modelling

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The characterization and monitoring of landfills has become a major concern, not only for assessing the associated environmental impact (e.g., groundwater contamination) but also for evaluating the potential for recovery of secondary resources, in particular for the production of raw materials and energy. For both objectives, it is crucial to have knowledge of the waste composition and the current landfill conditions (e.g. water saturation level). Near-surface geophysical surveys have been proven effective for the non-invasive investigation of landfills, in which different methods have been used depending on the specific survey targets. Because of its sensitivity to two subsurface physical properties, electrical conductivity (EC) and magnetic susceptibility (MS), frequency-domain electromagnetic (FDEM) induction has been successfully applied to the qualitative characterization of urban and industrial landfills, including mine tailings. Yet, due to the generally complex composition and strongly heterogeneous spatial distribution of waste deposits, reconstructing a reliable landfill model from surface geophysical measurements remains challenging. Geostatistical inversion emerges as powerful tool to improve the landfill modelling from geophysical data, allowing for a more detailed description of the spatial distribution of the properties of interest and the associated uncertainty. Additionally, it provides a flexible framework for integrating data from geophysical surveys and conventional sampling from drilling or trenching.

In this work, we present a new geostatistical inversion technique able for the simultaneous inversion of FDEM data for EC and MS, which optimize the landfill modelling procedure and is sensitive towards change on the physical properties of interest. This method is based on an iterative procedure where ensembles of subsurface models of EC and MS are generated with stochastic sequential simulation and co-simulation. These simulated models are conditioned locally by existing borehole data for these properties and by a spatial continuity pattern imposed by a variogram model. Synthetic instrument response data, including both the in-phase and quadrature-phase components of the FDEM response, are generated from each model using a forward model connecting the data domain (FDEM data) with the model domain (subsurface physical properties). The misfit between the observed and forward-modelled FDEM data, weighted according to the depth sensitivity of the FDEM response toward changes in EC and MS, is used to drive the generation of a new set of models in the next iteration. We illustrate the inversion procedure with synthetic landfill example data sets which were created based on real data

collected at a mine tailing in Portugal and a municipal solid waste landfill in Belgium.