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Optimal Experimental Design strategies for geoelectrical monitoring of fluid transport processes

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Electrical resistivity tomography (ERT) offers noninvasive monitoring capabilities for a wide range of environmentally relevant subsurface processes. Its sensitivity to fluid content and temperature changes positions it as an important tool for capturing dynamic processes such as the transport of groundwater pollutants, CO_2 or radionuclides. Particularly crucial is its ability to achieve this without intrusively accessing to the site, making it highly valuable in closed repositories like high-level radioactive waste (HLW) storage sites.

In highly sensitive and complex environments, as in the case of closed repositories, it is critical to maximize the information content of the planned (geo)physical measurements while keeping the costs to a minimum. Several past studies presented approaches to optimize both the sensor positions and the measurement configurations of ERT surveys for static or moving targets in the subsurface. This study extends Optimal Experimental Design (OED) strategies for geoelectrical measurements using information of active time-dependent transport processes in the subsurface. We present three different approaches for process monitoring and apply them to a simulated diffusive-advective transport process in a synthetic model over several time steps. The methods aim at focusing the survey only on the relevant part of the model, in this case the model region that is affected by the transport process. All presented approaches account for uncertain model input parameters by introducing an uncertainty factor in the ranking function. We present a purely model-driven and a purely data-driven active time-dependent OED approach. The first method utilizes the already acquired data from previous time steps to create predictive focusing masks for the next data set, the latter purely relies on model predictions to focus the survey. Moreover, we delineate a hybrid approach using both the simulated transport distance and the already acquired datasets. All three OED methods are compared to each other as well as to datasets that were acquired using standard electrode configurations.

The results of our synthetic study show that the adaptively designed, time-dependent OED approaches result in increased image quality compared to both standard surveys as well as time-independent OED methods. For slow transport processes or small monitoring intervals, the purely data-driven approach is most suitable, since no model predictions, and thus no possible model parametrization uncertainties, are incorporated. For faster transport processes or monitoring

strategies with larger acquisition intervals, the strategies that (partly) incorporate model predictions provide the most promising results.