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Hydrogeophysical characterization of heterogeneous aquifers: data integration and implications for hydrological predictions

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Knowledge of the detailed distribution of hydrological parameters in heterogeneous aquifers is a key prerequisite for accurate simulation of groundwater flow and contaminant transport. The integration of high-resolution geophysical data into the subsurface characterization problem has been shown in many cases to significantly improve our knowledge of hydrological parameters by providing information at spatial scales that are unattainable using conventional measurement techniques. However, the significance of many of the choices made during the complex process of geophysical data integration, such as data processing and inversion techniques as well as integration and simulation methodologies, is largely unexplored. In addition, evaluation of how much benefit is brought by the geophysical data for various types of hydrological models has not been thoroughly investigated. Understanding these issues is critical to making wise decisions about how to integrate the geophysical data. Here, we examine some of these issues for the case of porosity characterization in saturated heterogeneous aquifers using crosshole georadar and borehole porosity log data. To begin, we generate a number of realistically complex, stochastic porosity fields that exhibit varying degrees of continuity and structural heterogeneity. Next, we simulate the collection of crosshole georadar data between several boreholes in these fields, and the collection of porosity log data at the borehole locations. The synthetic georadar data are then tomographically inverted for the spatial distribution of electromagnetic wave velocity using a variety of inversion techniques. Together with the synthetic porosity logs, the resulting tomographic images are used to reconstruct the porosity field through

state-of-the-art Monte-Carlo-type conditional simulation techniques. The resulting realizations of porosity, obtained using the various combinations of inversion and data integration techniques, are then used as basis information to infer the hydraulic conductivity field and perform groundwater flow and contaminant transport simulations. Analyses of the thus obtained breakthrough curves allow us to assess the potential significance and viability of the various inversion and data integration methods for the detailed hydrological characterization of highly heterogeneous aquifers.