Multiple-scale integration of hydrological and geophysical data through Bayesian sequential simulation

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Significant progress has been made with regard to the quantitative integration of geophysical and hydrological data at the local scale. However, extending corresponding approaches to the regional scale still represents a major challenge, yet is critically important for the development of groundwater flow and contaminant transport models. To address this issue, we have developed a regional-scale hydrogeophysical data integration technique based on a two-step Bayesian sequential simulation procedure. The objective is to simulate the regional-scale distribution of a hydraulic parameter based on spatially exhaustive, but poorly resolved, measurements of a pertinent geophysical parameter and locally highly resolved, but spatially sparse, measurements of the considered geophysical and hydraulic parameters. To this end, our approach first involves linking the low- and high-resolution geophysical data via a downscaling procedure before relating the downscaled regional-scale geophysical data to the high-resolution hydraulic parameter field. We first show the application of this methodology to a realistic synthetic scenario represented by collocated high-resolution borehole measurements of the hydraulic and electrical conductivities and spatially exhaustive, low-resolution electrical conductivity estimates obtained from electrical resistivity tomography (ERT). The overall viability of the method is tested and verified by performing and comparing flow and transport simulations through the original and simulated hydraulic conductivity fields. The corresponding results indicate that the proposed data integration procedure does indeed allow for obtaining faithful estimates of the regional-scale hydraulic conductivity structure and reliable predictions of the transport characteristics over long, regional-scale distances. The approach is then applied to a field scenario, where we consider collocated high-resolution measurements of the electrical conductivity, measured using a cone penetrometer testing (CPT) system, and the hydraulic conductivity, estimated from EM flowmeter and slug test measurements, in combination with low-resolution exhaustive electrical conductivity estimates obtained from dipole-dipole ERT meausurements.