Hydrogeophysical Data Assimilation for Characterizing Aquifer Heterogeneity at a Groundwater and River Water Interface

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Dynamic exchange between groundwater and river water is the dominant force that controls hydrological and biogeochemical processes at their interface. Accurate characterization of heterogeneous aquifer permeability at this interface is critical for understanding and modeling coupled hydro-biogeochemical processes that occur within their interaction zone. The distinct contrast in specific conductivity (e.g., dissolved salts) between river water and groundwater allows application of a cost-effective technology called time-lapse electrical resistivity tomography (ERT, see poster by Johnson et al.). ERT can provide indirect spatial-temporal data for characterizing aquifer permeability by imaging the change in subsurface electrical conductivity driven by mixing between groundwater and river water. We installed a 300 m by 300 m three-dimensional ERT array to monitor the temporal dynamics of river water intrusion and retreat along a major river corridor. The resulting four-dimensional electrical geophysical data was assimilated to invert for the underlying permeability field using ensemble-based algorithms (e.g., ensemble Kalman filter and ensemble smoother).

A new high-performance multi-process code was developed by coupling a flow and transport code (PFLOTRAN) with an ERT imaging code (E4D). The coupled code provides key modeling attributes of multi-physics processes, parallel efficiency, and multi-realization simulation capability for data assimilation. We sequentially assimilated both well-based point measurements of water table elevation and specific conductance, and spatially/temporally continuous ERT images with ensemble-based data assimilation techniques. Our study demonstrates the effectiveness of joint hydrogeophysical data assimilation for characterizing hydrologic properties in the groundwater and river water interaction zone. The integration of multi-scale and multi-type data with a complex multi-physics model through Bayesian data assimilation techniques, and the use of high performance computing to meet the intense computational demand was a significant scientific achievement. The resulting permeability field provides essential insights on the hydraulic controls on river water intrusion and the locations of biogeochemical hotspots where nutrients from groundwater and surface water converge.