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Parameter Estimation of a Decision-Support Seawater Intrusion Model Using Multiple Well and Geophysical Data

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In coastal areas, seawater intrusion is a main driver of groundwater salinization and numerical models are widely used to support sustainable groundwater management. Sharp interface models, in which mixing between freshwater and seawater is not explicitly simulated, have fast run times which enable the implementation of parameter estimation and uncertainty analysis. These are essential steps for decision-support modeling, however their implementation in sharp interface models has remained limited. Few guidelines exist regarding which observations to use, and what processing and weighting strategies to employ. We developed a data assimilation framework for a regional, sharp interface model designed for management purposes. We built a sharp interface model for an island aquifer using the SWI2 package for MODFLOW. We then extracted freshwater head observations from shallow wells, pumping wells and deep open wells, and observations of the seawater-freshwater interface from deep open wells, time-domain electromagnetic (TDEM) and electrical resistivity tomography (ERT) surveys. After quantification of measurement uncertainties, parameter estimation was conducted with PEST and a data worth analysis was carried out using a linear approach. Model residuals provided insight on the potential of different observation groups to constrain parameter estimation. The data worth analysis provided insight on these groups' importance in reducing the uncertainty of model forecasts. Overall a satisfying fit was obtained between simulated and observed data, but observations from deep open wells were biased. While observations from deep open wells and geophysical surveys had a low signal-to-noise ratio, parameter estimation effectively reduced predictive uncertainty. Interface observations, especially from geophysical surveys, were essential to reduce the uncertainty of model forecasts. The use of different types of observations is discussed and recommendations are provided for future data collection strategies in coastal aquifers. This framework was developed in the Magdalen Islands (Quebec, Canada) and could be carried out more systematically for sharp interface seawater intrusion modeling.