Controlling the seawater intrusions: coupling groundwater model and geophysical data

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Abstract:

The process of seawater intrusions into the freshwater aquifers occurs naturally, but also as a result of increased groundwater extraction. Particularly in dry regions with high water demand, it is important to have a good understanding of the process and to apply good management measures. Different types of models to capture this complex process involving two phase flow and variable boundary conditions have already been proposed and implemented. However, for large coastal regions the main issue lies in groundwater management planning, specifically in how to adjust the future groundwater extraction or injection rates with respect to location of the saltwater intrusions, which is also a goal of this study.

Obtaining the direct measurements of salinity in large areas through standard groundwater sampling can be costly and difficult due to the miscibility of both freshwater and saltwater. Using indirect observations by geophysical methods (e.g. DC resistivity) can provide larger amount of observation data points with lower costs.

We suggest an optimization framework which links the hydrogeological model with geophysical datasets (at this point synthetic observation data). The dynamics of the system are represented by a vertical 2D model for transient groundwater flow in a confined aquifer based on discretized flow and solute mass balance equations. Finding the ideal management scheme under validity of groundwater model leads to an optimal control problem.

Kalman filtering techniques are often used for such problems. However, while the Kalman filter is as an algorithm that updates the states estimates after each time step, we formulate an optimization problem looking at the entire sequence of observation data. Successive state variables (e.g. piezometric heads) can be expressed as dependent on initial states, for which we assume known *a priori* estimates of mean and variance and some control vector (representing the external fluxes and pumping rates throughout the process). In the linear case of one phase flow, we can analytically express the solution for the control vector in closed form as a function of past measurements and estimated states. For the variable density flow, the process dynamic is nonlinear. One option is to linearize it for short time steps or solve it with numerical iterative techniques, and only after that find the optimal control vector. The developed algorithm should stay numerically stable, and remain computationally efficient while working with large datasets.