Most of humans live in coastal and alluvial plains. Sustainable water supply systems are essential for drinking water production while long-term groundwater access ensures its geothermal use. Owing to climate change and anthropogenic activities, groundwater resources will be increasingly threatened throughout the twenty-first century. In the context of over-development, any effort to overcome groundwater mining at the expense of better understanding groundwater management problems may be misguided. A combination of robust measuring technologies and reliable predictions based on numerical models are necessary to estimate better hydrogeological parameters. Sparse and continuous data are increasingly being used conjunctively in hydrogeological modeling and inverse calibration to alleviate extrapolation and subjective interpretation. In hydrogeology, electrical resistivity tomography (ERT) gives quantitative and qualitative information on salinity and temperature distribution. ERT offers a means for mapping the subsurface hydrogeological structures and the hydrologic process dynamics in both space and time. The integration of ERT data to hydrogeological calibration is particularly suited to define the hydrogeological models quantitatively and qualitatively. In a deterministic framework, hydrogeophysical inversion methods may be particularly useful for predictive analysis and assessment of groundwater pre-emptive management strategies.

This work focuses on calibrating physically-based and spatially distributed groundwater flow and transport models with non-to minimally invasive electrical tomography. The general objective is to provide better estimates of hydrogeological parameters on two relevant problems: seawater intrusion in coastal areas and geothermal energy in shallow environments. We compare methods to integrate quantitatively ERT data, possibly other hydrologic or geological data, with existing information to hydrogeological models. Two hydrogeophysical inversion schemes are developed and a thorough comparison of an uncoupled and a coupled quantitative approach based on the use of surface ERT only is performed. The uncoupled hydrogeophysical inversion involves constraining hydraulic parameters using geophysically-derived data and first requires a geophysical inversion, after which the geophysical parameters are converted to hydrologic data through a petrophysical relationship. The inverse hydrological calibration is then performed on these inferred hydrological data. The coupled hydrogeophysical inversion involves constraining hydraulic parameters using geophysical data through a forward hydrogeophysical model in which the hydrologic data are converted to resistivities through a petrophysical relationship. A geophysical forward problem is then solved for the geophysical data. The inverse hydrological calibration is performed on the inferred geophysical observations. In both schemes, we show that an independent geophysical inversion is required to delineate heterogeneous bodies. In this context, we study how to derive informative content of ERT images and therefore ERT-derived hydrologic data and ERT-derived geometry. We show that a quantitative appraisal (the cumulative sensitivity) must be used as a proxy for filtering areas correctly resolved.

Our developments are demonstrated on several benchmark SWI models (numerical and analytical), a thermohydrologic model and a field test. We show that the reliability of estimated SWI model parameters with the uncoupled approach depends on ERT image appraisal, on geophysical data collection strategy and hydrogeological model conceptualization. The ERT image appraisal plays a key role in retrieving high quality ERT-derived data and helps discriminate different measurement arrays. It is particularly useful in preventing the integration of noise-related artefacts in the conceptualization. We endeavor to quantify the modeling error by a thorough comparison of different strategies to assess the effect of decreasing model conceptual errors to hydrogeological calibration. In the SWI analytical models, we highlight the subjectivity of the uncoupled approach due to the nature of the required hydrologic data (sharp interface). We demonstrate that the conjunctive use of an image appraisal tool with the well-known Ghyben-Herzberg solution is needed to infer reliable ERT-derived observation data. We further demonstrate that a SWI analytical solution may be used to calibrate an equivalent hydraulic parameter based on an ERT dataset generated from a density-dependent groundwater flow model. In the thermohydrologic model, we show that the effectiveness of the uncoupled scheme in calibrating heat transport parameters may be hampered due to the regularization constraint in the geophysical inversion. We demonstrate the importance of a noise level-related filter on the time-lapse ERT images aimed at properly quantifying the spatio-temporal ERT-derived temperature changes. We also advocate the use of a physically-based constraint on the ERT-derived temperatures to account for spatial mixing of waters and to cope indirectly with the smoothing effect in the ERT images. In each application, the coupled approach significantly prevails over the uncoupled scheme in terms of reliability of the parameter estimates when no model conceptual error exists.