BRUNETTI Carlotta (2018) : Bayesian model selection in hydrogeophysics and hydrogeology

Abstract

Groundwater is a fundamental source of drinking water. With population growth, land use changes, economic activities, urbanisation and climate change, a safe and sustainable management of groundwater resources is becoming more and more critical. This needs to rely on an accurate characterisation of the hydrogeological heterogeneity in the subsurface, which is a challenging task. First, the subsurface is hidden from sight and collecting local hydrogeological measurements is difficult or too expensive. Second, geophysical methods can effectively support such measurements but, at the same time, they require the definition of petrophysical relationships that are often uncertain and poorly known. Third, the spatial geological structure of groundwater systems is complex and the definition of the corresponding conceptual model is non-unique. This leads to one of the main (and often ignored) sources of uncertainty in modelling studies, namely conceptual uncertainty. Bayesian model selection relying on evidence computation and Bayes factors provides a quantitative approach for comparing and ranking alternative conceptual models and, therefore, accounting for conceptual uncertainty. In this thesis, we will investigate the use of Bayesian model selection in hydrogeophysics and hydrogeology by answering the following research questions: (1) Are geophysical data suitable for guiding model selection in hydrogeology? (2) Can petrophysical uncertainty and its spatial structure be inferred in hydrogeophysical studies and how do they impact Bayesian inversion and model selection? (3) How can we achieve model selection when targeting geologically-realistic hydrogeological conceptual models represented by training images? These objectives will be addressed using a full Bayesian approach based on Markov chain Monte Carlo algorithms. The research goals will be then explored in light of synthetic and field-based case studies with the purpose of characterising spatially-distributed porosity or hydraulic conductivity fields in aquifers. From the first comparative study of Bayesian model selection in hydrogeophysics ever, we conclude that geophysical methods can be valuable in providing guidance about which hydrogeological representation of the subsurface is the most supported by the available data among a set of competing conceptual models. We then propose a method to account for and infer the spatially-correlated uncertainty of petrophysical relationships. We find that this approach leads to less bias, more realistic uncertainty quantification and less overconfident model selection. Moreover, we propose and successfully apply a new methodology for performing Bayesian model selection among geologically-realistic conceptual models represented by training images.

Key words: Bayesian model selection, hydrogeophysics, evidence, petrophysical uncertainty, conceptual uncertainty, Markov chain Monte Carlo, training image