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Using Markov chains for modeling hydrogeological parameters in environmental problems

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As we know, there are several critical environmental factors that are affected by hydrogeological characteristics of subsurface media (e.g. hydraulic conductivities of an aquifer that provides the drinking water of an area). However there is very limited and indirect access to subsurface as well as economical and technical limitations in measuring required parameters. Moreover, for modeling the continuous parameters, one would better to model the type of media (e.g. soil or rock types) in which the fluids have migration.

Therefore the attempts have been focused in recent years on developing modern modeling and estimation methods that try to make three-dimensional models of all parameters having limited numbers of measured points.

Geostatistical methods have paved the way for making as exact models as possible as well as providing some evaluation parameters to estimate errors and uncertainties by calculating and modeling spatial variability of parameters and their relation with one another.

Traditional geostatistical methods use variance, covariance (e.g. variogram, covariogram…) or similar parameters for modeling spatial uncertainty. For modeling the type of media e.g. a new parameter called indicator is assigned to every measured point which is set to one when that category exists and zero when it lacks. In tradition geostatistical methods however, the some facts in addition to the mathematical structure of data such as geological parameters are not considered in models directly. Moreover, the indicator methods always face special problems such as vague (co)variogram models, order relation problems and some nonsense estimations.

On the other hand some newer methods have been developed which make use of Markov chains and: improve spatial variability modeling even in little data conditions, reduce order relation and non-sense estimations significantly, provide better ways of integrating extra information in our models (such as physical facts, general knowledge, geological information…), easier considering asymmetry in data structure, simpler inter-class correlating, and finally easier and faster algorithms of modeling.

Among mentioned Markov chain (MC) methods, in this article we are going to review and compare the following approaches: Transition probability-based Markov chain indicator geostatistics, coupled Markov chain methods (CMC), Transition probability Markov chain geostatistics (TPG).