Geophysical Research Abstracts
Vol. 15, EGU2013-11953, 2013
EGU General Assembly 2013
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Insights from Modelling the Spatial Dependence Structure of Hydraulic Conductivity at the MADE Site Using Spatial Copulas

Claus Haslauer (1) and Geoff Bohling (2)

(1) Univeristy of Tübingen, Centre of Applied Geoscience, Tübingen, Germany (claus.haslauer@uni-tuebingen.de), (2) Kansas Geological Survey, University of Kansas, Kansas, USA (geoff@kgs.ku.edu)

Hydraulic conductivity (K) is a fundamental parameter that influences groundwater flow and solute transport. Measurements of K are limited and uncertain. Moreover, the spatial structure of K, which impacts the groundwater velocity field and hence directly influences the advective spreading of a solute migrating in the subsurface, is commonly described by approaches using second order moments.

Spatial copulas have in the recent past been applied successfully to model the spatial dependence structure of heterogeneous subsurface datasets. At the MADE site, hydraulic conductivity (K) has been measured in exceptional detail. Two independently collected data-sets were used for this study: (1) $\sim$2000 flowmeter based K measurements, and (2) $\sim$20,000 direct-push based K measurements. These datasets exhibit a very heterogeneous (Var[ln(K)]>2) spatially distributed K field. A copula analysis reveals that the spatial dependence structure of the flowmeter and direct-push datasets are essentially the same. A spatial copula analysis factors out the influence of the marginal distribution of the property under investigation. This independence from the marginal distributions allows the copula analysis to reveal the underlying similarity between the spatial dependence structures of the flowmeter and direct-push datasets despite two complicating factors: 1) an overall offset between the datasets, with direct-push K values being, on average, roughly a factor of five lower than flowmeter K values, due at least in part to opposite biases between the two measurement techniques, and 2) the presence of some anomalously high K values in the direct-push dataset due to a lower limit on accurately measureable pressure responses in high-K zones. In addition, the vertical resolution of the direct-push dataset is ten times finer than that of the flowmeter dataset. Upscaling the direct-push data to compensate for this difference resulted in little change to the spatial structure.

The objective of the presented work is to use multidimensional spatial copulas to describe and model the spatial dependence of the spatial structure of K at the heterogeneous MADE site, and evaluate the effects of this multidimensional description on solute transport.