Geophysical Research Abstracts
Vol. 20, EGU2018-5427, 2018
EGU General Assembly 2018

Confidence interval estimation of hydraulic heads at unobserved locations using stationary stochastic models and geologic interpretations

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Effective design of groundwater observation networks, requires accurate and robust hydraulic head estimates at multiple locations in an aquifer. In most groundwater applications, however, the spatial extent of geologic formations is generally assessed based on subjective geologic interpretations in the light of geologic maps, soil surveys, and/or geophysical data. Under this setting, understanding the sources and parameterizing the uncertainty in hydraulic head estimation constitutes an important topic for engineering applications. In this work, we study the effect of the statistical structure of hydraulic conductivity fields on the distribution of the absolute error in hydraulic head estimates at unobserved locations in an aquifer. We do so for one-dimensional confined media, using scaling and non-scaling stochastic representations of hydraulic conductivity, and obtain the distribution of the absolute error |e| as a function of the characteristic scale L of geologic formations, the standardized distance from the nearest measuring locations, and the small scale variability inside each formation. We show that the distribution of |e| has attributes (bounds, multi-modal features etc.) that can be parameterized based on L, and statistical characteristics (mean value, variance, quantiles etc.) that depend on the statistical structure of the aquifer at spatial scales l < L. We conclude by calculating the distribution of the maximum absolute error, and demonstrate that the validity of the stationarity assumption when modeling spatial heterogeneities in groundwater applications is a matter of the observation scale. Finally, we present confidence bounds for the absolute error in hydraulic head estimates in-between measuring locations, which encompass all possible structural dependencies in a stationary setting.