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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Technical note: Analytical solution for the mean drawdown of steady state pumping tests in two-dimensional isotropic heterogeneous aquifers" *by* A. Zech and S. Attinger

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In this technical note the authors (a) develop an analytical solution for mean steady state drawdown under horizontal flow to a well withdrawing water from a randomly heterogeneous aquifer at a constant rate and (b) suggest ways to evaluate properties of aquifer transmissivity on the basis of measured drawdowns. Their analysis is based on a Radial Coarse Graining (RCG) approach described in Schneider and Attinger (2008). It considers two versions of coarse grained transmissivity, termed ensemble

and local, given in parametric form as functions of radial distance from the well. The authors then propose ways to determine the corresponding parameters on the basis of measured drawdowns.

To properly review this note for HESS I found it necessary to study the above work of Schneider and Attinger (SA). Here I discovered what appear to be fundamental inconsistencies in their RCG approach. The development in SA starts with a stochastic representation of 2D steady flow in a random transmissivity field toward the well, subject to deterministic inner and outer boundary conditions. As we all know, this stochastic flow equation embodies two physical principles, conservation of (incompressible) water volume and Darcy's law. RCG a la SA consists of upscaling transmissivities through weighted spatial averaging with a weight function that depends on radial distance. The resulting spatially averaged transmissivity is considered to be deterministic. Replacing transmissivity in the original stochastic equation with its upscaled version thus renders this equation deterministic in what the authors consider, and label, RCG drawdown. It is this "RCG" equation that Zech and Attinger rely on in the technical note under review.

Unfortunately, the latter RCG equation is not consistent with the two physical principles on which the original stochastic equation rests. To preserve these principles SA should have applied RCG to the original stochastic flow equation, not just to transmissivity. Averaging the original equation would have resulted in a modified flow equation, preserving the underlying physics, but including a new integrodifferential term with an integrand that contains both transmissivity and hydraulic gradient. This nonlocal cross term would be equivalent to the residual flux term in the probabilistically averaged stochastic flow equation of Neuman and Orr (Neuman, S.P. and S. Orr, Prediction of Steady State Flow in Nonuniform Geologic Media by Conditional Moments: Exact Nonlocal Formalism, Effective Conductivities and Weak Approximation, Water Resour. Res., 29(2), 341-364, 1993). By (inadvertently?) dropping this mixed integrodifferential term, SA have introduced a bias into their resulting RCG flow equation the magnitude of which could be large or small, depending on circumstances. We know from subsequent numerical solutions of the Neuman and Orr stochastic moment equations that ignoring their residual flux, as has been common in the stochastic literature, may result in unjustifiably large biases.

A lesser but not insignificant issue with RCG is the treatment of RCG transmissivity as deterministic: there is nothing in the SA approach to guarantee that weighted volume averaging of randomly varying transmissivity would itself not be random, albeit with a lesser variance (but longer correlation scales).

On a minor note, it would have been fair for Zech and Attinger to juxtapose their proposed pumping test interpretation method with that of Neuman et al. (Neuman, S.P., A. Guadagnini, and M. Riva, Type-curve estimation of statistical heterogeneity, Water Resour. Res., 40, W04201, doi:10.1029/2003WR002405, 2004).

I regret that, given the above fundamental inconsistencies, I cannot recommend publication of the technical note by Zech and Attinger in HESS.

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