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Interactive Comment

Interactive comment on "Geostatistical modeling of spatial variability of water retention curves" *by* H. Saito et al.

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The NP method (now called the IF method) chosen is indeed arbitrary. 11 pairs were used simply because there were 11 saturation-water tension pairs available for the data set. We then reduced the number of pairs to 6, as you can see in the manuscript, to evaluate if there would be any impact on conclusions. Of course, to use 10 pairs would be an obvious alternative option. The conclusion depends on how well retention curves are constructed at each location. Therefore, what we can do in practice is to carefully examine how many saturation-pressure pairs we need to construct reasonably a representative retention curve. The answer should depend strongly on soil types. We have added additional discussions regarding the choice of the number of pairs in the NP approach (the IF approach in the revised manuscript).

Regarding other interpolation techniques, we totally agree with Dr. Harter that there are other methods available. The objective is, however, not to compare different interpolation methods, but to investigate the difference between interpolate-first or interpolate-later approaches. Kriging was used primarily because there existed spatial correlation for each variable. As can be seen in Figures 7 & 8, all semivariograms are well-structured. Many alternative interpolation techniques do not account for spatial correlation. Therefore, using kriging makes the most sense. We have added additional comments on other interpolation methods in Introduction.

In the revised manuscript, we included and discussed the distribution of the saturation values and water retention parameters. Ordinary kriging indeed works best when the distribution of the parameter is Gaussian. In many cases, however, when the distribution is not Gaussian, OK is still the best choice among other kriging algorithms where data transformation and back-transformation are necessary. Different kriging algorithms were compared in Saito and Goovaerts (2000) when the distribution of cadmium concentration data was highly skewed and there were a lot of censored data. Results show that when data are sparse, indicator kriging or log-normal kriging outperforms ordinary kriging in terms of making cleanup decisions when those decisions were made based on estimated concentrations. However, when more data is available, ordinary kriging performs as good as other kriging algorithms do.

In the revised manuscript, in addition to ordinary kriging, we have also used indicator kriging, in which the shape of distributions can be basically anything. Results show that OK outperforms IK in terms of prediction errors when the FI approach is taken.

We would like also thank Dr. Harter for very critical but constructive comments on very fundamental points of this study. Dr. Harter is right that we did not perform any uncertainty analysis in this manuscript. That was because considering uncertainty was beyond the scope of this study. As for kriging variance, we used that information when retention model functions were fit to constructed retention curves in the revised manuscript. Results are almost the same with those in the original manuscript. The proposed approach was not intended to provide a random space function. There are a number of studies that use kriged values as input data to a given function for further investigation. In a work done by Dr. Ye (Ye et al., 2007), a heterogeneous field of retention parameters was generated through a geostatistical interpolation technique, cokriging, and pedo-transfer functions. Then, using generated soil hydraulic parameters, variably-saturated water flow was simulated. Simulated water contents agreed well with observed values. Ye et al. concluded that their approach to generate heterogeneous soil hydraulic parameter fields has a lot of potential and is better than traditional inverse methods. In those studies, kriged values were treated as “actual” values. To avoid any confusion and misleading readers, we did omit the term “spatial variability” from our revised manuscript as suggested by Dr. Harter. We still have the term “geostatistical” but did not use the term to imply that this work is done in the stochastic framework. In the revised manuscript, we emphasize that the focus of this study is to generate heterogeneous retention parameters using a spatial interpolation technique, namely kriging.

Related to the above reply, we would like to comment on kriging variance. We agree with Dr. Harter that kriging variance can be a good indicator of uncertainty about the estimated value. However, kriging variance does not give us the variance of the estimated value. The rigorous uncertainty analysis requires either stochastic simulation or indicator type kriging where one can construct a conditional cumulative distribution function at any unsampled location. This is, however, certainly beyond the scope of this study.

The title of the manuscript has been modified to “An alternative deterministic method for the spatial interpolation of water retention parameters” accounting for comments made by other reviewers as well. We omit the word geostatistical and the word spatial-variability from the revised manuscript almost completely. There are a few locations where we still have “geostatistical” but no “spatial variability.”

We totally agree that there are other interpolation methods available. However, none of

HESSD

5, S2603–S2606, 2009

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those Dr. Harter mentioned accounts for spatial correlation of variables. In this sense, we believe that kriging is the best option for interpolation. In addition, the objective of this study is not to compare different interpolation techniques but to compare two different approaches to obtain retention parameters at unsampled locations. To stick with this objective, instead of trying all different kinds of interpolation methods, we use kriging only for interpolation.

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