Hydrol. Earth Syst. Sci. Discuss., 2, S1094–S1098, 2005
www.copernicus.org/EGU/hess/hessd/2/S1094/
European Geosciences Union


Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Geostatistical investigation into the temporal evolution of spatial structure in a shallow water table" *by* S. W. Lyon et al.

**S. W. Lyon et al.**

Received and published: 29 November 2005

The authors thank Reviewer 1 for great comments on this manuscript. The main comment of Reviewer 1 is that the manuscript suffers due to a lack of structure in describing the methodology. As a result, the reviewer continues, the manuscript sections become mixed and there are duplications that should be eliminated. This is a good comment and we have restructured sections of the text to provide a clear, concise description of our analysis. This was accomplished in three ways: 1) shortening brief description of methods in the introduction, 2) subtitles in the methods section, and 3) eliminating duplications present in section 4.1 and 4.2 in the results.

The majority of Reviewer 1 comments are contained in detailed comments and addressed below with the reviewer comment in *italics*. All typos and minor wording suggestions from the reviewer have been accepted.

*Pg1685,ln20: I don't understand the term non linear variability...* 'Non-linear variability' was a poorly selected term. The non-linearity refers to the dynamics of the saturated regions (i.e., their changing in space with respect to time).

*Pg1687,ln2: Any type of loggers can be employed to monitor something...* The authors did not intend the loggers used were the only option to sample from the field-scale to the watershed scale, but that loggers of this type can be used.

*Methods: You should better explain why you use indicator...* Indicator approaches allow for comprehensive structural analysis and are robust to outlier values (Journel, 1983). In this way, indicator approaches allow for greater spatial correlation of extreme values (Journel and Alabert, 1989; Rubin and Journel, 1991). By using a time-variant median, and thus guaranteeing that half the points are above and half below the threshold, we obtain the best defined, with greatest range of continuity and some confidence concerning sparse data, sample indicator semivariograms (Journel, 1983). This makes indicator kriging more appropriate than ordinary kriging when dealing with highly variant phenomena. Also, in order to incorporate soft data and prior probabilities, indicator variables need to be invoked. Co-variogram calculations for comparison with the ranges observed could be an interesting next step for this vein of research. The authors feel that an analysis of that type would not add specifically to the process presented in this particular manuscript.

*Generally I miss a statistical characterization of the database...* The statistical characterization has been included in the revised text to add to the significance of this research.

*Please give information on which lag you used for variogram calculation and what was the maximum distance of your pairs...* The sample semivariograms were calculated using 10 bins with lags of 15 meters. The number of bins and lag distance were selected using the rule of thumb that the number of bins multiplied by the lag distance should be approximately half the maximum separation distance (288 meters for this site).

*Pg1692,ln10: Please explain why indicator variograms are superior for finding spatial clustering of measurements...* Indicator semivariograms better represent highly variant phenomena, composed of extreme values, making them better for identifying spatial clusters. The logic is that indicator variables better identify the spatial structure associated with extreme values (e.g., saturated locations) and that these values tend to be connected and continuous in natural fields (Western et al., 1998a).

*Pg1693,ln10: spatial structure is isotropic ... comment on that?* Flow paths tend to meander on the hillslope. The converging areas do not form straight paths perpendicular to the stream. This creates a spatial structure that has slight anisotropy occurring both in the northwest-southeast and northeast-southwest orientation (corresponding to the dominant gradient in the upper and lower hillslope, respectively). The topography is too diffuse to justify incorporating these small, multidirectional anisotropy trends.

*Pg1693,ln15: Why didn't you use Kriging to interpolate, estimate the extent of the total saturated area?* Kriging was not used to estimate the extent of total saturated area because indicator kriging only provides a probability of exceeding a threshold. It does not tell you if a location is saturated or not. It would require a further assumption on the acceptable probability of exceeding the time-variable median water table to generate a map of saturated area.

*Pg 1693: My feeling is you should better explain how introduced the soft information into the kriging process. What about an equation?* This is a good comment. We agree that adding an equation helps explain how soft data is created from the STWI map in a concise manner. The average prior probability for exceeding the median water table was computed for each STWI interval. A linear equation relating the two was created that defined prior probability at locations with no observations and was used to create a spatially continuous prior probability map (soft data) based on STWI. Residuals were evaluated between the hard data available at sampling locations and the soft data map.

These residuals where then interpolated and merged with the soft data to incorporated prior probability.

*Table 2: It would be interesting to see the absolute values of the RMSE, not only the relative changes when after incorporating soft information...* These absolute values have been added to the revised text in Table 2.

*What was the variance within the validation sample compared to the variance in the calibration sample?* The average variance for the six events was 0.25 for the calibration sample and 0.26 for the validation sample for the indicator variables. The average variance for the six events was 56.9 $cm^2$ for the calibration sample and 72.8 $cm^2$ for the validation sample for the depth to water table. These values further demonstrate why indicators were selected for this analysis and give a good representation of extreme events. Looking at the variance for the calibration and validation sample sets, the difference is large when considering the actual water table, but this difference is much smaller when data is transformed into indicator variables.

*It would be very interesting to have a look at the monthly spatial patterns of the exceeding frequencies...* This is represented in the comparison of exceeding frequency and STWI. This comparison (Figure 6) shows that the points which are "more wetter than average" correspond to locations with high STWI (i.e., converging areas with shallow soils) during wet periods. This topography driven pathway for the wet areas is not existent in this analysis for drier conditions.

*This hints that the pattern is patchy during intermediate wet conditions and exhibits larger structures at the dry and the wet branch. Can you explain this for the dry case?* During the dry periods, there is a reduction in variance and an increase in range for the short time interval analysis. The water table is more uniform in space for these periods. Thus, there are longer ranges during these periods of highly continuous dry conditions. Then, when water tables rise, they rise in clusters that force a reduction in ranges. Once the hillslope is wet 'enough' these patches connect and expand to create large, uniform wet regions and large ranges.

*Figure 6: The correlations suggest that at the monthly scale topography is a reasonable predictor for the spatial pattern of patches with higher than average water tables in spring, but does not explain anything in summer. This contradicts partly the statement on page 1701 line 16, that the topographic index turned out to be a good predictor for the pattern of saturation during a long term simulation. Can you comment on this?* The long term simulation refered to on page 1701 line 16 was conducted on a monthly interval scale and showed that STWI was a good predictor during wet periods and not necessarily over the entire long-term simulation.

*Pg1699,ln1: A decreasing range does not mean that wet spots are "closer together"...* This is a correct statement from Reviewer 1. Locations where the water table is likely to rise during rainfall events have a shorter spatial structure during wet conditions than during dry where they constitute a more highly continuous spatial field. This is stated in the revised text

*Conclusion: The presented results allow some nice conclusions, especially on the usefulness of patterns for model validation. My feeling is, the authors should bring this out a little clearer in their final conclusions...* The authors agree that this type of analysis is especially useful in the realm of hydrological modeling and thank the reviewer for pointing this out.

ADDITIONAL REFERENCES

Journel, A. G. and Alabert, F.: Non-Gaussian data expansion in the earth sciences, Terra Nova, 1, 123-134, 1989.

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Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 1683, 2005.