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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.

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SUMMARY Within there study the authors shed light on the temporal development of shallow water tables on a hillslope located in the Catskill Mountains using geostatistical methods. The spatial pattern of water tables from 44 locations, observed at a 5 minutes interval for a period of 6 months (March- August), were analysed at the event and the monthly time scale. On the event time scale water table measurements were transformed into binary data that indicated whether a local water table observation is larger than the spatial median of all measurements and analysed with indicator variograms. Hence the binary variable indicates whether the location is “wetter” than the average. On the monthly time scale the authors calculated the frequency how often a measurement exceeded the spatial median of water tables. These exceeding frequencies were



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analysed with normal variograms as well as correlated with the topographical wetness index. At both time scales exponential variograms were employed to estimate nugget, sill and range of the experimental variograms. Finally the authors employed indicator kriging with and without soft information to estimate the spatial pattern of probabilities that the water table exceeds the spatial median at the event scale for 6 events with high antecedent soil moisture. As soft information the authors used exceeding frequencies they derived from the monthly scale.

On the event scale the authors show nicely that the ranges of their binary variables exhibit large a temporal variation and that, during in average wet conditions, high ranges coincide with high discharge in the stream and a large extent of saturated areas. The authors show furthermore that the correlation between topographical wetness index and the monthly frequencies that the water table locally exceeds the median is quite high during wet spring condition and drops to zero during summer. This hints that topographic control on local saturation is high in spring but almost zero during summer conditions.

EVALUATION The proposed study gives useful insight in the spatio-temporal dynamics of saturated areas at the slope scale on different time scale and demonstrates the usefulness of geostatistical methods for analysing a spatial set of water table data. Thus the paper is highly suitable for the audience of HESS and has the potential to become a valuable contribution. Unfortunately, the paper suffers from quite a number of short comings concerning the manuscript structure, the explanation of underlying methods and results. The authors should revise there manuscript addressing the general and detailed comments below.

GENERAL COMMENTS Ţ The manuscript is not well structured and suffers from a number of duplications! The “brief description” of the methodological approach at the end of the Introduction on page 1689 too detailed should shortened. Especially the presentation of the methods as well as the presentation of the results is not well structured and mixed! What about using subheadings as additional orientation in section 3?



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It is not necessary to repeat methodological details and the purpose of the analysis in the beginning of the results sections, as the authors do in section 4.1 and 4.2. Ţ The methods section it is not transparent and the explanation of geostatistical methods is not appropriate! It is very difficult to understand how you implemented the soft data into the indicator kriging, how you used the topographic index for this. The reader can guess what you did, after checking the figures, but this does not make an effective paper!

DETAILED COMMENTS Abstract Ţ Page 1684, line 20: Maybe change the word region into catchment or hillslope, as a study on the hillslope scale is not capable to yield results that characterise hydrological behaviour of a region.

Introduction Ţ Page 1685, 20: I don't understand the term non linear variability, can variability be linear or non linear? Dynamics can! Ţ Pager 1686, line 9: Typo change hydrologist to hydrologists. Ţ Page 1687, line15: Any type of loggers can be employed to monitor something from the field to the watershed scale, depends on extend, support, spacing and money. Do you mean that these loggers are cheap? Ţ Page 1687, line15: The authors name the sill to be spatial variance of measurements. I don't understand this term. To me the sill is the part of total variance that may be explained by the spatial arrangement of the measurement network. The sill is a function of spacing of the measurement points and the total extend of the network (Blösch, 1996; scale and scaling and hydrology).

Site description and data Ţ Page 1690, line 13: typo replace conductive by conductivity

Methods Ţ You should better explain why you use indicator variables. The explanation comes in the discussion section, which is too late. By selecting a variable that just indicates, whether a location is wetter than average, you loose information about the spatial variance and how far the points deviate from the average. Maybe the standardised deviation of a local measurement from the median would be the better choice? Ţ Given the measurement time series at each location you could easily compute a co-variogram for different events (covariance between pairs plotted against distance), which would be an average measure for the spatial co-variance during an event. A correlation length could be defined via an integral scale or as the distance where co-variance gets zero. Would be interesting to compare your ranges with these correlation lengths Ţ Generally I miss a statistical characterisation of the database in terms of total spatial variance and mean, median on the monthly scale as well as for selected events of the daily scale! Without this information the significance of your results, especially the temporal variations of the ranges on the event scale, is difficult to judge. Ţ Please give information on which lag you used for variogram calculation and what was the maximum distance of your pairs. Ţ Page 1692, line 10: Please explain why indicator variograms are superior for finding spatial clustering of measurements. Ţ Page 1692, line: 23: I don't think that the term normalised is correct here! The nugget and sill of an indicator variogram do not sum up to the total spatial variance of the water table measurements at a given time. This is no normalisation but a scaling. Ţ Page 1693, line 10: It is interesting that the spatial structure is isotropic. At a hillslope with shallow bedrock and permeable soils I would expect larger ranges perpendicular to the gradient. Can you comment on that? Ţ Page 1693, line 15: As you have a non constant average spacing in your grid, the Thiesen polygons in the upper part of the slope are larger than in the lower part. So these points get higher weights when comparing the ranges of the variograms with the extent of you saturated areas. This is critical as points in the steeper upper parts of the hill are for sure less representative for the water tables than points in the lower points of the hill. Why didn't you use Kriging to interpolate, estimate the extent of the total saturated area? Ţ Page 1693: The selection of the monthly probability for exceeding the median of the depth to water table seems a good choice! My feeling is you should better explain how introduced the soft information into the kriging process. The point with the linear model to predict the monthly prior probability at locations with no observations becomes clear later, but it is not clear in this section. What about an equation?

Results and Discussion Ţ It is not necessary to repeat methodological details in the



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beginning of 4.1 and 4.2. Ţ Page 1696, line 27: typo replace 0.54 by 0.054 Ţ Table 2: It would be interesting to see the absolute values of the RMSE, not only the relative changes when after incorporating soft information. Ţ How did you select the 30% for the cross validation, randomly. What was the variance within the validation sample compared to the variance in the calibration sample? Ţ It would be very interesting to have a look at the monthly spatial patterns of the exceeding frequencies. The worst thing that can happen, is that the exceeding frequency is 0.5, means the point is as often wetter than average as it is dryer. Any deviation from 0.5 is therefore interesting and gives information on the pattern of possible pathways and whether it changes on the monthly scale. Ţ Your results on the daily scale suggest high ranges during conditions with high median depths of water tables (dry), decreasing ranges for intermediate medians and again rising values during conditions with low median depths of water tables (wet 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? Ţ Figure 6: It would be helpful if you provided the spatial average and variance of the monthly exceeding frequencies, also to judge the reduction of RMSE in Table 2. Did you test the significance of the correlation coefficients? 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? Ţ Page 1699 line 1: An decreasing range does not mean that wet spots are “closer together”, but that the spatial pattern gets more “patchy”, exhibiting preferably isolated patches and no large scale, more homogeneous structures

Conclusion Ţ 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.

Erwin Zehe

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