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Hydrology and Earth System Sciences Discussions

Interactive comment on "Plot and field scale soil moisture dynamics and subsurface wetness control on runoff generation in a headwater in the Ore Mountains" *by* E. Zehe et al.

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Response to Reviewer 1 by Erwin Zehe et al.

Anonymous Referee #1 Received and published: 18 January 2010

Overview The study investigates the innovative Spatial TDR (STDR) technology to assess the spatial-temporal soil moisture behaviour in two (grassland and forested) experimental sites located in the German eastern Ore mountains. Moreover, the relationship between soil moisture and runoff for the headwater catchment (16 km2) including the experimental areas was analyzed.

Response: We sincerely thank the reviewer for his constructive comments, that were most valuable for improving this manuscript (in particular also for the interesting reference pointed). The following lines explain how we addressed the recommendations.

General Comments The paper is well written and structured and the topic is relevant for the HESS reader. The paper presents a novel technology and the language is fluent and precise. However, in my opinion, several aspects should be better discussed before its publication.

1) The first one concerns the selection of an appropriate strategy to set up a soil moisture monitoring network to be used for improving the understanding of the rainfall-runoff behaviour at the catchment scale. The authors, in the introduction, stated that " Soil moisture at the headwater scale exhibits huge spatial variability and single or even distributed TDR measurements yield non-representative data". However, several studies reported that a few number of soil moisture measurements can be conveniently used for the estimation of the wetness conditions at the catchment scale, and, hence, to improve rainfall-runoff modelling (Aubert et al., 2003; Pfister et al., 2003; Anctil et al., 2008; Brocca et al., 2009; Tramblay et al., 2009). On the other hand, many studies analyzing the temporal stability of soil moisture spatial pattern revealed that, also for large areas, the temporal behaviour of spatial mean soil moisture can be derived from a small number of point measurements (see e.g. Grayson andWestern, 1998; De Rosnay et al., 2009; Brocca et al., 2010). In this study (see P7516L24-26) soil moisture measurements carried out in an area of 400 m2 were found correlated with the runoff response of the catchment having a drainage area of 16 km2 (five order of magnitude larger!). This result agrees well with those mentioned above and confirms the possibility to monitor soil moisture in few locations, also for "large" catchments. Therefore, I suggest to reformulate the introduction and the discussion sections considering these comments. I agree with the authors that the STDR technology represents a clear improvement for soil moisture monitoring at the catchment scale (mainly because the soil moisture profile can be derived) but it was demonstrated that also a network of ground

soil moisture sensors (and also satellite derived soil moisture estimates) can furnish useful information for rainfall-runoff modelling and even for flood warning purposes.

Response: Good point to be pointed out. Indeed we found that distributed timeseries within the same cluster were often highly correlated. This is good news as stated by the reviewer, as distrubed point sampling may yield very valuable information about distributed soil moisture. Even a single TDR could thus yield important information to estimate runoff coefficients in this catchment.We will stress this even stronger in the revised manuscript and refer to the suggested papers. However, what it is also important to stress is that a single TDR probe does a) not yield representative data on the mean value of such an ensemble (defined as we did) in such a heterogeneous environment. This has implications for control of nonlinear proceses for instance ET and for the usefullness of single measurments for groundtruthing remote sensing data (unfortunately this is forgotten sometimes).

2) As mentioned by the authors in the conclusions section, the geostatistical analysis carried out for a small area has little sense. In this case, in my opinion, the analysis of the relationship between other statistical quantities as mean, standard deviation and coefficient of variation can be more valuable (see e.g. De Lannoy et al., 2006; Famiglietti et al., 2008).

Response: This is surely true for the forested site, were ranges are constant 50 % of the total extend. At the grassland site, however, lags were dynamic and short enough to be detected with this setup. In the present manuscript we already compared the mean, standard deviation at both sites and discussed the coefficients of variations as rather constant in time (0.22 and a narrow range between 0.23). Which underpins the temporal stability of the pattern outlined by the reviewer. We are a little concerned N of the sample is too small to allow calculation of unbiased skewness in most of the cases.

At the grassland think that the variogram points out valuable information (see our comment to your detailed comment below)

3) In the regression analysis I suggest to use not only the runoff coefficient as indicator of the runoff response at catchment scale. Several authors suggested to compute the soil potential maximum retention parameter, S, of the Soil Conservation Service - Curve Number method (Huang et al., 2007; Brocca et al., 2009; Tramblay et al., 2009) that reproduces at best the runoff volume and to use this value as benchmark for the comparison with in-situ soil moisture observations. Otherwise, the initial soil moisture conditions derived by a physically based approach (as the CATFLOW model used in this study) can be more conveniently used for this purpose. Due to the strong non linearity of the relation between soil moisture and runoff a comparison with these indicators can be more meaningful for the assessment of the representativeness of the TDR cluster at catchment scale. Moreover, why antecedent precipitation indices were not tested? Why a multiple regression analysis was not performed? I suggest to investigate also these two aspects.

Response: Excellent idea we will use multiple regressions in the revised paper and additonally the rank correlation coefficient , which is more suitable for nonlinear cases as the Pearsons coefficient. We admit the curve number might be usefull in some cases and refer to these studies. However, we prefer not to add the curve number to the statistical analysis, as it is not an observable quantity and the physical basis may be seen controversal,

4) The application of the CATFLOW model for soil moisture simulation is very poorly described. I do not understand if the model parameters are calibrated or estimated through specific measurements. For instance, in the study area and field instrumentation section the authors reported that C2 site is characterized by a higher infiltrability (beyond the measurement range) than C1 site. However, looking at Table 2 the ks values for the two sites are quite similar. If the model parameters are calibrated it is not surprising the good accordance between model simulation and observations (see P7518L13-14). When the parameters are calibrated, even with more simple models similar results can be obtained. Moreover, it is not amazing that for long term soil

moisture simulations the more significant process is the evapotranspiration (see e.g. Brocca et al., 2008). Finally, mainly if model parameters are calibrated, I suggest to use also the 2008 period (that should be available) for model validation to give a more clear picture of the model performance. C3147

Response: Very True, this needs more flesh. In the revised paper we will discuss the different soil setups we tried to assess sensitivity of the model for these parameter and explain they are based on observations (there was not calibration involved). The plant morpholigcal parameters to characterise the average annual coarse of LAI; soil cover, root depth etc. were derived based on detailed field survey in the Weiherbachbachment (Zehe et al. 2001 Phys. Chem. Earth B). However, these values are of coarse dependent on the climate and landscape setting. A simple transfer was thus not successfull. In the revised manuscript we will explain that only slight changes in the annual maxima (10%) of LAI and plant cover, with the same annual cycle had a strong influence and provided the good match shown in the graphs. We will provide a table that relates the sensitiy (changes in model performance, and overall ET) to the changes in these parameter values to better underpin this part.

On this basis, the paper can be recommended for publication in HESS journal, provided the comments and suggestions given above are addressed.

Specific Comments/ Technical Corrections P7505L15: see also Aubert et al. (2003); Anctil et al. (2008); Brocca et al. (2009) and Tramblay et al. (2009) for studies relating soil moisture observations and runoff. P7506L16-18: Other authors found opposite results. For instance, a direct relationship between mean and standard deviation was frequently observed analyzing soil moisture spatial patterns (see e.g Figure 1 in Brocca et al., 2007). In general, the relationship type depends on the climatic and soil characteristics of the study area (Teuling and Troch, 2005). The same occurs for the mean-correlation length relationship. P7507L1: "km" to modify as "km2"

Response: We will discuss this and fix the typo

P7507L29: Graeff et al., 2009 is reported 2 times in the reference section. Use 2009a and 2009b to distinguish the 2 papers. Moreover, the acceptance of the paper Graeff et al. (2009) submitted to HESSD is needed for this study because it reports the description of the STDR technology. Likely, a brief description should be included in this paper.

Response: Sorry for the sloppiness

P7509L18-19: A more detailed description of the two grids where soil moisture measurements were carried out is needed. For instance, what is the location of the two sites within the catchment? Which is the distance between C1 and C2 sites? Which is the area covered by the two grids? Which is the average spacing between measurement points?

Response: Will be presented in more detail

P7512L17: "...and the separated..." to modify as "...and then separated..." P7512L23-24: I suppose that the recession coefficients are computed for the recession limb of the hydrograph but it should be better specified.

Response: will be done

P7512L27: Why was only the grassland site used for the comparison with the catchment runoff response? Were the results for the forested site not good? If so please specify because it is relevant to know which are the better locations for soil moisture monitoring.

Response: Good point, we will discuss this

P7513L11: Please specify the SVAT acronym. Response: Will be fixed.

P7514L2-4: I suggest to include a figure showing the employed numerical scheme. It helps the reader to better understand the CATFLOW model application. Response: Will be addressed as outline above

P7514L6: "...26 October 2008." to modify as "26 October 2007.". Response: Will be addressed as outlined above.

P7515L8-10: Please reformulate the sentence because it is not clear.

Response: Will be checked

P7515L20-21: What does one order of magnitude smaller mean? Please specify better this part where the spatial and temporal variability of soil moisture patterns is compared because it is confusing for me. I do not understand if the spatial variability is more significant than the temporal variability or viceversa. Response: We wanted to express that hourly soil moisture changes are one order of magnitude smaller, we reformulate this part

P7515L24-25: Likely, the low correlation length is due to the small area investigated. Response: Total extend of the net is 15 by 15 m.this is thus true in the forestes site, but not at the grassland site

P7516L8-10: The sill to nugget ratio equal to 1 means that, for the forested site, the spatial soil moisture patterns are not organized (see also Figure 4 on the right). Therefore, the correlation length obtained for this site has a very low sense.

Response: We disaggree. Nugget to Sill ratios at the grassland site are 1/6, 1/4, 1/3, this reflects exactly the the ratio of the uncorrelated part of the total variance to the correlated part. Thus there is structure, but the range is rather short. Zimmermann et al. (2008)found similar short ranges of ksat at a hillslope in Ecuador. At the grassland site, we aggree that the variogramm is biased by the extend of the net. This was however clearly explained in the discussion

P7517L28: Show the first guess line of Maurer in Figure 9. Response: will be done as outlined above P7519L20: "...total runoff production is stronger in, ..." to modify as "...total runoff production is stronger in autumn (?), ...". Response: Will be checked P7520L3: This is true for long term soil moisture dynamic simulation. For short term

analysis the infiltration parameters are more significant. Please specify. Response: We of course aggree

Figure 1: The figure showing the catchment (in the middle) is too small. Please enlarge it and include the hydrometeorological network location. Response: Will be improved.

Figure 3: For the lower panel the y label is missing Response: will be fixed.

Thanks very much again,

Erwin Zehe

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 7503, 2009.