Interactive comment on "McMaster Mesonet Soil Moisture Dataset: Description and Spatio-Temporal Variability Analysis" by K. C. Kornelsen and P. Coulibaly

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Dear Editor and Referee,

We thank Referee #1 for the comments received and positive appreciation of the manuscript. We will seek to satisfy the referee's comments in the following paragraphs.

Regarding the overview, we would like to make a point of clarification. The network is composed of 216 TDR probes measuring volumetric soil moisture, where each of the 4 sites contains 9 stations monitoring soil moisture at 6 depths each. A CS-616 probe is installed at each of the six depths, thus a total of 54 probes at each of the 4 sites.In addition to the CS-probes, 63 Stevens Hydra-probes are co-located at Kelso 1 with additional probes at a depth of 5 cm. This last point will be further clarified in the main manuscript.

1 General Comments

Comment 1: I found quite surprising that the authors refer to four sites. In fact, two sites (i.e., Kelso 1 and Kelso 2) are located in the same hillslope and I do not understand why they are considered separately in the paper. Can the authors add the explanation for that?

We thank the referee for pointing this out, as the point deserves some clarification. The primary objective of this manuscript is to provide a comprehensive description of the dataset, and while these two locations are co-located the data are monitored and collected as two independent data sets. Thus, it has always been natural to the authors to internally refer to these as separate data sets. Similarly, the data are independently stored and distributed for each site and thus K1 and K2 can be provided to users independently. The following lines have been added to Section 2.2 to clarify this point.

The K1 and K2 sites are located adjacent to each other to allow sampling of a larger area. However, both datasets are collected independently and will herein often be considered as distinct data inspite of their co-location for the purposes of describing the dataset. It is noteworthy that both CS-616 probes and Stevens probes are co-located only at Kelso 1 (K1). For other sites only CS-616 probes are used.

Comment 2: Moreover, it is not clear to me if the network is aimed at monitoring soil moisture for the whole basin (Hamilton-Halton Watershed) that has a drainage area of 1250

km2. Likely, the spatial representativeness of the three sites could be limited, even though the soil moisture temporal stability properties might allow the upscaling of the measurements. This is an interesting point that might be analyzed in further studies. However, I suggest adding a discussion on these aspects also in the present paper.

The referee is refered to Pg. 13999 Line 24 to Pg. 14000 Line 10. The aforementioned section is provided in the introduction section, which the authors acknowledge may not be an intuitive place to find this information, and it will therefore be reiterated with some discussion of scaling properties in the description section.

The McMaster Mesonet was primarily designed for SAR soil moisture retrieval validation and process understanding at a high spatial resolution. It is not necessarily expected that the soil moisture arrays are representative of the watershed as a whole. However, the sites were purposely located on three distinctly representative landscapes within the watershed and as such, may have potential for upscaling.

Comment 3: I expect that frozen and snow conditions usually occur in the study area during the winter season. This has a significant impact on the accuracy and reliability of in situ soil moisture measurements but no mentioning is made in the paper. I believe this is an important aspect that has to be better analyzed.

The authors agree with the referee that frozen conditions may (and likely due to some extent in this instance) impact the soil moisture measurements. However, to date a thorough analysis on this aspect has not been conducted and soil temperature data collected have not proven to be of sufficient quality for this undertaking. Based on limited soil temperature measurements from the Stevens Hydra-probes and one weather station, we have found that freezing is typically only a concern for the upper 30 cm, although we do not have data to represent extremely long cold periods. The coldest recorded soil temperature at 10 cm is about -2.5°C, but temperatures of about 0°C are more common in the winter months. It is typical in the watershed, for air temperatures to fluctuate above and below 0°C during the winter and therefore the watershed does not necessarily experience the prolonged cold often expected of Canada. While we express this information for this response, we do not feel the soil temperature data is of sufficient extent or quality for publication at this point. A benefit of the hourly high resolution soil moisture data available is that erroneous data (as might be caused by freezing conditions) can be better noticed. Based on experience with this data, the authors do not believe freezing has a significant detrimental impact on the dataset. As mentioned, while we do not feel a proper analysis is possible at this time, the authors agree with the referee and this aspect should be addressed in future data analysis. In the revision, a cautionary note and discussion of the impacts of frozen soil will be made in conjunction with the analysis of the soil moisture data in the winter season, as well as a caution to potential users of the dataset.

Comment 4a): In the "Results" section, the statistical and temporal stability analyses of the measured soil moisture dataset is carried out. However, the description is difficult to be

followed. In my opinion, too much emphasis is given in describing the behaviour at single stations for single storm events (e.g. at pages 14012 and 14013-14014). I am lost in the analysis of GR site where the behaviour of each single location is investigated. The same in the analysis for the single storm events where the change in the rankings between locations should be analyzed. I am not saying that these analyses should be removed, but synthesized for giving space to the analysis of the overall dataset (neglected in the current version of the paper).

Comment 4b):For instance, it would be interesting to visualize the relationship between spatial variability (variance or standard deviation) and mean soil moisture at different sites and depths. This is shown in Figure 6 but it is difficult to be seen. The same applies for the temporal stability analysis, the classical figure of the relative differences might be included. In fact, this data set could provide further insights for understanding the soil moisture temporal stability in a "new" (with respect to previous studies) climatic region (see the recent review paper by Vanderlinden et al. (2012). I am aware that many papers have the same figures and analysis, but it is fundamental for this type of works the intercomparison of the results that can be easily done if some "standardization" is made (e.g. Brocca et al. (2007), also cited in the paper).

In response to comment 4a) the authors feel it is important that behaviour at the especially dynamic stations be characterized in keeping with the purpose of the manuscript, that being to introduce the dataset, the study site and some of the processes operating at the landscape therein. We also agree with the reviewer that this section of the manuscript is easy to get lost in and will revise it as the referee has suggested by greater synthesis. We will also include some broad discussion/analysis of the overall dataset, but are hesitant to directly compare (i.e. analyze relative difference of entire dataset) because the data are not representative of the entire watershed but rather three distinct landscapes at a field scale. We believe this level of synthesis is in keeping with the comments made by the referee.

With respect to Comment 4b), we agree with the reviewer about the importance of ‘standardization’ with respect to these common data analyses. In the revision we will include figures showing the relationship between the mean soil moisture state and variability as well as some ‘classical’ relative difference figures. This will also be used for the analysis of the overall dataset as mentioned previously.

2 Specific Comments

P14004, L4-5: Some further information on the measured weather parameters might be added. For instance, are water level and discharge data available in the catchment? This could be of interest for the combined use of soil moisture and runoff data from hydrologists. Are snowfall and snow height measured?

The following lines have been added to Section 2.2:

While not continously recorded by the McMaster Mesonet, limited snowfall and snow depth measurements in and near the watershed are available from Environment Canada weather stations. In addition to meteorological data, water level, discharge and ground water data are available independently from Environment Canada's HYDAT database (www.ec.gc.ca) and the Ontario Ministry of the Environment (www.ene.gov.on.ca).

P14004, L15: It is not clear if Stevens Hydra Probes are installed for each TDR probe at K1. Please specify.

The above line has been amended to:

At the K1 site, Stevens Hydra Probes were installed with each CS-616 TDR probe in order to provide a comparison between the two data products. The Hydra Probes were additionally installed at 5 cm depth at each station at K1. .

P14004, L17: It would be interesting to see at the comparison between gravimetric and TDR soil moisture measurements to evaluate the accuracy of the data.

During the installation of the CS-616 TDR probes, the Campbell Scientific staff confirmed the soil at the study sites was sufficiently similar to that used for the standard calibration curves. Therefore, gravimetric sampling for calibration was not carried out at that time, but is being considered for research in the near future.

P14006, L7: In Equation (5) it should be $\_{ij}$ (as in equation (2)).

Equation 5 is correct. This equation is consistent with Equation 3, where the aggregation to the daily time step occurs prior to the spatial aggregation being characterized in Equation 5.

P14006, L18: Should be $\_{ijk}$ (not $\_{jk}$) at station i, at depth j and time k.

The above correction has been made.

P14007, L15: Tables 1 and 3 are hard to read. Probably it would be better to visualize the data in a figure.

The authors believe there is too much data in these tables to allow for proper visual discrimination in a figure. We are also conscious of the fact that this manuscript is already heavy on large figures.

P14007, L21: Change "deep soil" with "wet soil"?

Deep referred to soil moisture in the lower layers. The term 'deep' has been amended for clarity to:

soil moisture at depths greater than 50 and 70 cm at GR/OR and Kelso respectively,

P14007, L23: Should be Table 1.

The above correction has been made.

P14008, L11-13: This sentence is not clear here, please explain better.

Sentence amended to:

The temporal stability analysis will follow, focusing on seasonal trends, temporal consistency of the mean relative difference ranks and the time required for spatial organization to return following a disturbance.

P14009, L2-3: The higher spatial variability in the "no-transition" periods is hard to be seen (see General Comments).

This will be addressed by enlarging the figure in the final HESS manuscript, and will be complimented by a 'classical' MRD figure as discussed in the response to Comment 4, which will better show the variability.

P14013, L10-...: This analysis is very hard to be followed.

Similar to comment 4, this section will be synthesized in the revision. This will enhance the clarity of this section.

Figures: Some figures need improvements. The labels in most of them are too small.
For instance, it will be very difficult to see figure 7 labels and details also in the published version.

The figures in HESSD were slightly compressed. We will work with HESS production staff to ensure the figures submitted for the final production version do not have this problem.