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Hydrology and Earth System Sciences Discussions

Interactive comment on "Spatial variability and its scale dependency of observed and modeled soil moisture under different climate conditions" *by* B. Li and M. Rodell

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Review of "Spatial Variability and its Scale Dependency of Observed and Modeled Soil Moisture under Different Climate Conditions" by Li and Rodell

Evaluation: In this study, spatial statistics of in situ soil moisture measurements from the SCAN network, modelled and satellite retrieved soil moisture were examined over three different climate regions in the US were analysed with respect to spatial variability and its relation to mean soil moisture as well as its scale dependency.

Although the paper is very well written and structured I have found several problems

concerning the data, the method as well as the interpretation of the results of the analysis. In addition the benefit of this study is not well presented.

I therefore recommend a major revision of the paper.

General comments:

1. The remotely sensed soil moisture data as well as the model estimates are representing an average value within a large footprint/model grid, whereas ground-based measurements of the SCAN stations can be considered as point measurements because the spatial scale of each usually represents only ∼4–5 cm diameter. Due to the high spatial variability of soil moisture, a large number of measurements would be needed to accurately represent the mean soil moisture content within such footprints/model grids. In this study however, the point measurements of the SCAN network are directly compared with AMSR-E and NLDAS data. In addition, the vertical representation of soil moisture is different in all data sets (SCAN: ∼3-7 cm; AMSR-E: 0-2 cm; NLDAS: 0-10 cm). Given the high vertical soil moisture gradients especially during drying periods, this will lead to significant biases in the analysis. In addition, there are several other aspects that limit the comparability of the data sets: SCAN stations are always located on agricultural fields, whereas NLDAS and AMSR-E data are integrating over all land cover types; The AMSR-E data excludes rainfall periods thus underestimating maximum soil moisture values; The variability of the NLDAS estimates is largely dictated by the spatial resolution of the parameterisation fields (e.g. soil maps). In consequence the significance of the interpretations in this study is rather limited.

2. The scale effects should be discussed in the framework of the "scale triplet" composed of spacing, support, and extent suggested by Western and Blöschl (1999). Spacing refers to the distance between measurements, support refers to the effective area or volume that each measurement represents, and extent is the total area of the spatial domain.

3. The data from Famiglietti (2008) was gathered during several campaigns (between 1997 and 2003) and therefore should not directly be compared with the continuously monitored and temporally averaged SCAN data from 2008. In addition the measurement was done by vertically inserting a probe into the soil (0-6 cm), whereas the SCAN data was measured at 5 cm depth (sampling depth: $\sim$3-7 cm). Therefore I would suggest not combining these data sets.

4. It is well known that the knowledge of the scalability of soil moisture at the subgrid scale is important, e.g. using information on soil moisture variance to consider subgrid-scale heterogeneity, because ignoring subgrid-scale heterogeneity can produce a substantial bias in hydrological modelling results. In this study, scalability of soil moisture at the continental scale is investigated. However, the benefit for knowing the scaling behaviour at such a large scale, e.g. beyond 100-200 km, is not provided. I personally doubt that the scalability soil moisture beyond 100-200 km is still meaningful, especially at the time scale of only one year.

Specific comments:

Title: This study uses soil moisture data sets from a period of 198 days, which is hardly adequate to characterise climate conditions (>10 years would be needed). Therefore, it should read "... over different climate regions"

L42 Why should the higher number of soil moisture products increase the need for characterizing soil moisture variability?

L82 Better "is true for" instead of "can be said about"

L107 How many SCAN sites were used in this study?

L125 The term "dielectric constant" is outdated. Please use "dielectric permittivity" and also mention the sensor type.

L127 In which way will the one-sided landuse type of the SCAN sites influence the analysis results?

L153 This is not true, since the AMSR-E retrievals have a higher spatial resolution than the very scattered SCAN stations.

L172 Please explain the meaning of "grid/pixel containing the SCAN site for Noah and AMSR-E retrievals"

L172-173 Are the SCAN point measurements aggregated to grid/pixels of Noah and AMSR-E?

L176 Better: "limited to SCAN measurements at 5 cm and to the top layer of Noah estimates."

L197 It should be mentioned that the convex is only due to merging the different subsets. None of the subsets does show a convex of its own. In fact the western sub-sets are showing rather a positive trend, whereas no clear trends are visible for the other sub-sets. Therefore I would rather call it "apparent" convex shape.

L213-215 The existence of a lower and a upper bound of the soil moisture variability – mean soil moisture content relationship is not a sufficient explanation of the convex shape. A multitude of controls are shaping this relationship at the small catchment scale, e.g. soil texture and structure, topography, vegetation, climate and antecedent soil moisture (e.g. Rosenbaum et al., 2012).

L215-217 In fact "merging" and not "splitting" produced the apparent upper convex shape.

L220-222 In fact all subsets a scattered and no convex shape is visible at all. The statement that the Eastern subsets would form a decreasing trend due to the lack of dynamic range is pure speculation.

L227-229 In fact not the spatial resolution but the sampling volume increases from SCAN to AMSR-E. Thus the SCAN data is influenced by small scale variability which is averaged in the AMSR-E data. The spatial resolution of the NLDAS is not only dictated by the model discretization, but also by the spatial resolution of the forcing

data and parameterization fields.

L236-237 What might be the reason for the insensitivity to season changes?

L243 Please add "...and non-correlation with precipitation."

L244-248 This discussion can be better explain using the scatter plots of Fig. 3.

L278-281 This test has limited significance due to fact that NLDAS cannot represent the sub-scale soil moisture variability. This is also expressed by the low increase in StD presented in Table 1 (e.g. for Utah from 0.042 to 0.045).

L284-285 This conclusion is unjustified since in the test only Noah estimates have been used.

L307 It has to be noted that the data from Famiglietti (2008) was gathered during several campaigns and therefore cannot directly be compared with continuously monitored and temporally averaged soil water content data.

L308 Please explain why you did not took mean std values from Famiglietti (2008) shown in Fig. 11; taking std values at the 0.2 mean soil moisture from their Figure 9 seems to be an odd choice.

L325-330 Please try to give an explanation for this phenomena. My guess is that the scattered SCAN data is not well suited for a scale dependency analysis.

L355 Actually the authors are not providing new evidence to the theory that the upward convex is caused by the boundness of soil moisture. Instead the authors are suggesting that this is a mathematical fact (L213-215). Other authors (e.g. Vereecken et al., 2007) have suggested that the shape of relationship between soil moisture variability and mean soil moisture is caused by the non-linearity of the soil retention function. Using highly resolved long-term soil moisture data sets at the catchment scale, Rosenbaum et al. (2012) recently demonstrated that the relationship also shows clear hysteresis effects, suggesting that a combination of different processes, e.g. throughfall

pattern, root water uptake, lateral redistribution, preferential flows etc., are responsible for the shape of the relationship.

L369-370 Please explain why the mean values are of special importance.

L381-384 I have read this sentence several times but I was not able comprehend its meaning. Since it comprises the key conclusion of this study it should be reformulated in a way that it can be understood by readers with an average understanding of this topic.

L384-387 This sentence also does not make any sense to me.

L391 Please define of "anomalous soil moisture"

L396 Why should soil moisture anomalies be more critical for the validation of GRACE data products compared then to other satellite base soil moisture products?

Figures Fig. 1 The blue rectangles representing the sub-regions are not well discernible. It would be helpful, if the names of the regions could be shown in the map. Fig. 2 The graphs are showing not volumetric percentages, but m^3/m^3 values Fig. 3 The graphs are showing not volumetric percentages, but m^3/m^3 values

References

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Vereecken, H., T. Kamai, T. Harter, R. Kasteel, J. Hopmans, and J. Vanderborght. 2007. Explaining soil moisture variability as a function of mean soil moisture: A stochastic unsaturated flow perspective. Geophys. Res. Le 34:L22402, doi:10.1029/2007GL031813.

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