We would like to thank Dr. Heye Bogena for the many comments and questions which should help improve the quality of the paper. The following are your comments and our responses.

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.

We never compared Noah/AMSR-E soil moisture with SCAN measurements at an individual grid cell or footprint which would require more sampling within the support of Noah or AMSR-E. As to the question if the number of SCAN sites in each region is enough to represent the spatial mean, we conducted the sampling density test using Noah soil moisture (i.e.,Figure 6) which suggests that they are sufficient to represent the true mean of Noah soil moisture. Although this test does not necessarily imply the same is true for SCAN soil moisture, it still gives us some confidence that the spatial mean represented by SCAN data is a reasonable approximation to the true spatial mean (at the point scale) in each region because there are good correlations between SCAN and Noah soil moisture (Table 3).

Yes, differences in sensing depths and other factors could lead to biases in soil moisture. But, it was never the goal of this study to evaluate Noah and AMSR-E soil moisture; instead, the purpose of including them was to find a common control responsible for the behavior of spatial variability, specifically the upward convex which has been a focus of many studies. What we found out is that higher moments all show similar dependency on mean soil moisture (such as its distance to the lower and upper bounds), regardless of data types. Sensing depth, support and other environmental influences may affect spatial mean, but they do not change how spatial means determines the correlation between higher moments and spatial mean. Using Figure 7 of Rosenbaum et al. (2012) as an example: samples from different depths exhibited different degrees of spatial variability and mean values; but the control of mean soil moisture on the correlation between spatial variability and mean is the same: positive correlation when means are less than the mid-range (around 0.35 in that case) and negative when means are greater than the mid-range soil moisture. Similar dependency can be found in almost all other studies. So we do not believe the implication of this study is limited because of the difference in sensing depths and supports. However, we will discuss more about these differences and their potential impacts on spatial mean and clarify the purpose of the study in the revision.

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.

The impact of support on scale-dependency was discussed, but was in the context of spatial resolution. We can revise this section to specifically use support and also discuss the results in the context of scale triplet by Western and Blöschl (1999).

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: _3-7 cm). Therefore I would suggest not combining these data sets.

We understand your concerns. Rosenbaum et al. (2012) showed large discrepancies in spatial variability for soil moisture sampled at different depths because the study site was influenced by shallow groundwater tables. No shallow groundwater was reported in Famiglietti et al. (2008) or at SCAN sites and therefore, the averaged behavior of soil moisture at 5 cm should be close to that of 0-6 cm, especially for temporally averaged spatial variability. The difference between continuous sampling at SCAN sites and fewer sampling in field campaigns is alleviated, to certain degrees, by the use of temporally averaged spatial variability. As shown in Figure 4, the dynamic range of daily spatial variability in June-July (the sampling period of Famiglietti et al.) is about the same as that of the entire season. So the temporally averaged spatial variability from the SCAN sites should be comparable with the averaged values by Famiglietti that were obtained from different years. We will caution the readers about the difference between the two data sources and provide the above justification for combining them.

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.

In addition to validating the power law, such linear relationship can be used to obtain spatial variability at any intermediate scales where in situ measurements are not available. Whether such relationship has inter-annual variability needs to be further studied when more in situ data become available.

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"

Your suggestion can be taken.

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

Without appropriate validation, these products cannot be useful for hydrological applications. Validating them requires knowledge of soil moisture spatial variability which is still limited due to lack of in situ measurements in various climate and hydrological conditions. We will revise the section to be more specific.

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

Can be revised as you suggested.

L107 How many SCAN sites were used in this study?

The total number is 109. The number of SCAN sites in each region has been provided in Table 1.

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

Agreed.

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

Even though most SCAN sites are located in agricultural areas, crop types and their seasonality do vary even within each climate region. So the influence of land use, in terms of different crop types, is reflected in the recorded SCAN soil moisture. In addition, because of the large scales studies here, the major influences on soil moisture spatial variability are atmospheric forcing such as precipitation which was well sampled (in terms of mean) by the scattered SCAN sites as shown in Table 2.

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

Spatial resolution may not be the right term to use for SCAN data given their scarcity in space. We will revise it to use 'support'.

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

It means the grid or pixel in which a SCAN site is located.

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

No. They were treated as individual measurements in all the statistical calculations.

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

Agreed.

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.

Merging would sound like we merged the soil moisture data from all regions to calculate the statistics. We can revise it to use words like 'collectively' to reflect the fact that the convex contains statistics from different regions.

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).

Although we concluded that the boundedness of soil moisture is the root cause for the upward convex, it does not mean that other controls do not influence soil moisture spatial variability; rather, their impacts diminish as soil moisture approaches the lower and upper bound. Rosenbaum et al. (2012) explained the upward convex as,"*As ϑ dries towards ϑ_{crit} ,drainage, evaporation and root water uptake increase soil moisture variability. Below ϑ_{crit} ,soil moisture variability in humid regions is mainly controlled by the limited water availability for evaporation and root water uptake"*. ϑ_{crit} here is the mid-range soil moisture. A question regarding this explanation can be asked: why do impacts of ET and drainage peak at the mid-range soil moisture, not at other soil moisture values? In our opinion, such symmetric behavior around the mid-range soil moisture can only be explained using the boundedness of soil moisture. We will include the argument of Rosenbaum et al. (2012) in the discussion to encourage further discussions on this issue.

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

The continental US was first split into three climate regions so that statistics could be calculated within each region. We will emphasize the statistics from different regions 'collectively' formed the convex.

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.

We will revise it to be more precise. But we didn't say the eastern subsets form a decreasing trend here. In fact, we said Noah soil moisture failed to form a decreasing trend in these two regions.

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.

We will revise this section to use 'support' instead of 'spatial resolution' which is not appropriate for describing scattered SCAN data.

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

It is likely due to the reduced sensitivity of brightness temperature to moisture content in the peak growing season when vegetation water content is higher (Jackson, 1993). In addition, the shallow sensing depth of AMSR-E may not capture the seasonal change reflected in SCAN and Noah soil moisture.

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

Sure.

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

Will revise as suggested.

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).

The small change in StD in the sub-regions (Utah and Mis-Tenn) is an indication that the spatial variability sampled at the SCAN locations is very close to the true spatial variability of Noah soil moisture. We will indicate this test does not necessarily mean the spatial variability at the point scale is sufficiently sampled.

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

We will caution that it is only valid for Noah soil moisture.

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.

We will caution reader these differences. But we do not see anything fundamentally wrong about combining them, both of which are temporally averaged values. Just like Famiglietti et al. (2008), we had to use data from different experiments to gain more understanding about the nature of scale dependency when in situ measurements are limited.

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.

Figure 11 contains temporally averaged spatial variability and is more appropriate to use. This is our oversight. We re-created Fig.8 using data from their Fig11 and found that the fit of a linear relationship did not change much with the slope dropped to 0.085 from 0.11.

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.

The scattered nature of SCAN is a non-issue here because the phenomenon is observable in the scale dependencies of Noah and AMSR-E spatial variability which were derived using all grid data within each concentric square. It can be explained using the diminishing influence of supports on spatial variability as the extent scale increases. Specifically, at the certain large extent scale, the difference in supports becomes negligible and all data sets should yield the same degree of spatial variability. Because data sets with larger supports have lower spatial variability initially, they need to have larger increasing rate to reach to the same level of spatial variability as data in finer supports. We will include this explanation in the revision.

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.

If indeed the upward convex is caused by the boundedness of soil moisture, it should be observable at any scale. This study revealed this upward convex at scales that no other studies have investigated before. So we provided new evidence that the upward convex is caused by the boundedness.

As this explanation, i.e., the boundedness as the root cause for the convex, has not been widely accepted by the community, evidences were and are still needed to convince those in doubt, despite our belief it is a mathematical effect. Physical processes and properties my influence spatial variability, but their influences gradually diminish as soil moisture approaches the dry and wet end. As we argued early, the symmetric behavior of soil spatial variability with respect to the mid-range soil moisture, as shown by Rosenbaum et al. (2012), cannot be completely explained using physical processes and environmental influences alone.

Vereecken et al. (2007) used a closed form of soil moisture variance derived by Zhang et al. (1998) to demonstrate the relationship between spatial variability and mean soil moisture. What they failed to recognize is that the analytical solution was derived under very strict hydrological conditions: steady state flow (meaning no impact of precipitation and ET) and free-drainage (meaning no capillary force which is a very important factor determining the vertical flow of soil moisture near the surface). Statistically, deriving such solution also assumes a **normal** distribution for soil moisture which is not always true as we learned from this and previous studies: soil moisture becomes highly skewed, i.e, non-normal, when mean values approach the lower and upper bound. Therefore, when Vereecken et al. (2007) applied such solution to the full range of soil moisture, they violated this fundamental assumption which led to inconsistent results with what have been found in in situ measurements. For instance, the predicted spatial variability by Vereecken et al., (2007, Fig.2) never showed a noticeable decreasing trend when mean soil moisture approaches the upper bound. Although the spatial variability did drop to zero near the lower bound, it is because the b0 factor in equation (1), which depends on the inverse of mean suction head (Zhang et al, 1998), decreased to zero (the mean suction head increases to infinite as the soil becomes increasingly dry). In two plots (Fig.3, e and h), the relationship did exhibit an upward convex, but it was achieved by using a very large Cv value, 1, a violation of another assumption used in deriving the closed-form solution: the Cv of soil moisture was assumed to be very small, i.e., <<1, in order to omit the higher order perturbation terms (Zhang et al., 1998). In addition, the predicted Cv in 3 out of 4 soil types (Fig.3, Vereecken et al., 2007) has a bell shape while all other studies (e.g.,Famiglitte et al., 2008) showed an exponential decline of Cv with increasing mean soil moisture. In short, this analytical solution by Zhang et al. can only be used in very restricted hydrological conditions and limited soil moisture range to explain the contribution of individual hydraulic parameters to the total variability of soil moisture, not suitable for explaining the upward convex.

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

Because the proximity of mean soil moisture to the low and upper bounds determines the magnitude of spatial variability and skewness as well as the relationship of these higher moments with mean soil moisture: spatial variability is lower near the bound due to the boundedness. We will elaborate this more in the revision.

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.

What we meant was how close the mean to the lower and upper bounds determines the degree of spatial variability and skewness. The boundedness of soil moisture suppresses spatial variability and changes the skewness when mean soil moisture approaches the bounds.

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

Given the important role of spatial mean on spatial variability and skewness, any downscaling approach should try to maintain the mean as provided by satellite retrievals so that appropriate spatial variability and skewness can be achieved. Data assimilation is one of such approaches that can dynamically infuse satellite retrievals with finer scale features provided by model estimates while maintaining the retrieved spatial mean at each pixel.

L391 Please define of "anomalous soil moisture"

This should be soil moisture anomaly.

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?

Because other satellite derived soil moisture retrievals are full magnitudes of soil moisture, not anomalies. GRACE TWS are anomalies, with soil moisture anomaly as a major component.

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.

Yes, this figure can be improved.

Fig. 2 The graphs are showing not volumetric percentages, but m3/m3 values Fig. 3The graphs are showing not volumetric percentages, but m3/m3 values

The captions should use cm^3/cm^3.

References

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