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Interactive Comment

Interactive comment on "Closing the water balance with cosmic-ray soil moisture measurements and assessing their spatial variability within two semiarid watersheds" *by* A. P. Schreiner-McGraw et al.

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Response to Reviewer 1:

First of all, we thank Reviewer 1 for her/his comments that significantly helped us to improve the quality of our manuscript. In the following, we first describe the main changes that we made on the text based on the suggestions of all three reviewers and, then, we provide point-to-point answers to Reviewer 1's comments.

A. We separated the “Methods” section into “Study Area and Datasets” and “Methods”.

B. We better focused the main analyses and results of the manuscript, which can be summarized as follows: 1. Validation of cosmic-ray neutron probe sensing (CRNS) through distributed sensors and a novel method based on the water balance closing. 2. Utility of CRNS for hydrologic studies at the footprint scale, including (i) the quantification of the water balance fluxes over the 19-month period, and (ii) the improvement of the relations between evapotranspiration (ET) and soil moisture. These changes implied significant modifications in the Introduction, Methods and Results sections.

C. To give more importance to the main results reported in the previous point: 1. We reduced the part focused on the spatial variability of soil moisture and moved it to the section on the validation of the CRNS method through the distributed sensor network of soil moisture probes. 2. We completely removed analysis, discussion and one figure about the relations between spatial variability of soil moisture and ET.

D. We improved the description of the water balance approach for (i) validating the CRNS method and (ii) studying the fluxes at the CRNS footprint in continuous fashion. In doing so, we carefully explained each assumption to avoid any misunderstandings.

E. In the computation of the event-based water balance, we adopted a different measurement depth (z*) for each event, as requested by all reviewers. This implied an update of two figures and metrics reported in Table 4.

Point-by-point responses to Reviewer 1’s comments:

Reviewer 1 Comment: 1. The paper deals with many different topics (e.g. CRNS validation, water balance closing, soil moisture variability, comparison of two test sites). In consequence each of these topics is only dealt with in a rather superficially way and the reader is lost in too much and inconsistent information. In order to focus the paper, I suggest removing the sections on soil moisture variability.

Author Response and Actions Taken: As mentioned above, we reorganized the text to highlight the main two contributions of the paper: (i) improve our understanding of the CRNS method through two independent validation methods, and (ii) show how CRNS can be applied to study hydrologic processes at the footprint scale.

For this aim:

1. We modified the main analyses and results of the manuscript to focus attention on a few important points, which can be summarized as follows: âĂć Validation of cosmic-ray neutron probe sensing (CRNS) through distributed sensors and a novel method based on the water balance closing. âĂć Utility of CRNS for hydrologic studies at the footprint scale, including (i) the quantification of the water balance fluxes over the 19-month period, and (ii) the improvement of the relations between evapotranspiration (ET) and soil moisture.

The motivations for these studies have been discussed in the "Introduction" from page 3, line 18 to page 5, line 5.

2. We reduced the analysis on the relations between spatial variability and mean of soil moisture and we used it as further confirmation of the correspondence between soil moisture measurements from the distributed sensors and CRNS. As a result, this part was moved to Section 3.1 in the "Methods" (page 12 and line 17 on the new manuscript version) and to Section 4.1 in the "Results and Discussion" (page 17 and line 11 on the new manuscript version). In addition, Fig. 9 of the first draft is now Fig. 6.

3. We removed the analysis and discussion of the relations between spatial variability of soil moisture and ET. As a result, Fig. 11 was removed.

Reviewer 1 Comment: 2. There already exists a long list of papers dealing with the validation of the CRNS method for soil moisture determination and it was already shown that the methods works very well in arid systems due to the relatively low hydrogen content. Therefore, the good agreement with the in-situ measurements is of no surprise. However, also deviations were shown, e.g. during soil recessions. For the

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growing community it would be more interesting to learn more about reasons for such deviations.

Author Response and Actions Taken: This is an important and thoughtful comment. To address this, we propose a possible physical explanation for the reasons causing the deviations between the sensor network and the CRNS methods during soil moisture recessions. We think that, due to terrain features, soil moisture converges near the channels after the storms. While the CRNS sensor has the ability to measure soil moisture in these wetter areas, the distributed sensor network is not able to account for their presence, because only one sensor was located in a channel. This has been reported on page 16, lines 10-12.

Reviewer 1 Comment: 3. There are several contradictions in the manuscript. For instance, on the one hand it is stated that percolation at both site is mainly restricted to the first 40 cm and on the other hand it is stated that substantial amounts of precipitation percolated to deeper layers. In addition there are many ambiguities in the methods (e.g. assumptions concerning z*, z_m, and leakage).

Author Response and Actions Taken: Thank you for pointing this out. In the revised manuscript, we modified the text to explain each step of our methods. Specifically, in section 3.2, we distinguished the application of the water balance in event-based and in continuous fashions. For these cases, we justified our assumptions:

Event-based application of the water balance:

1. We modified the assumptions concerning zm. In the manuscript, we adopted a different depth z* for each event to calculate the water balance. This is important to reflect the varying measurement depth of CRNS. As a result, we did not use the symbol zm. This change is reflected in Fig. 6, and the text on page 14.

2. The event-based application of the water balance is focused on the rising limb of the soil moisture response. In this period, it is very unlikely that percolation to deeper layers

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occurs. As a result, for this case we assumed a leakage equal to zero (i.e., L = 0). This assumption has been tested at each site by checking the soil moisture measurements of sensors installed along a 1-m profile next to the EC tower. Note that z* is always above 1 m. We found that the percolation beyond a depth of ∼40 cm is infrequent at both sites during the duration of summer monsoon storms. This is explained in page 14, lines 1-5.

3. When we applied the water balance at the Jornada site (JER), we found 5 events where leakage most likely occurred (i.e., the change in soil moisture at the sensors at 30-cm depth is not negligible). This can be explained by the combination of: (i) high initial soil moisture due to the occurrence of these events near the end of the monsoon, and (ii) the large amount of rainfall for these storms.

Continuous application of the water balance:

1. The measurement depth was varied every day, selecting the minimum daily-average measurement depth between the two days being compared (see equation 7 in new manuscript).

2. Percolation can occur on a time scale of several days during winter precipitation (e.g., Franz et al., 2012b; Templeton et al., 2014; Pierini et al., 2014). Thus, in principle, L is not 0 and it is calculated as L= O – ET, where O is the flux (fCNRS) out the depth z*, measured by the CRNS, and ET is the evapotranspiration measured by the EC tower. This is explained in page 14, lines 18-22.

Reviewer 1 Comment: 4. The methods section should be better structured. For instance, the soil water balance based on the CRS and the water balance closing should be presented together.

Author Response and Actions Taken: We agree with Reviewer 1. Given the length of the "Methods" section, we have created a section on "Study Areas and Datasets", including:

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2.1: Study Sites and Their General Characteristics (as in the first version of the draft). 2.2: Distributed Sensor Networks at the Small Watershed Scale (as in the first version of the draft). 2.3: Cosmic-ray Soil Moisture Sensing Method

The "Methods" section is now organized into the following sub-sections:

3.1: Comparison of CRNS to Distributed Network of Soil Moisture Sensors (Validation of CRNS via distributed soil moisture measurements. In the new manuscript version, we moved here the analysis of the relations between spatial variability and soil moisture). 3.2: CRNS Water Balance Analyses Methods (Water balance approaches used for the validation of the CRNS method and the analysis of the water balance fluxes at the footprint). 3.3: Relation between Evapotranspiration and Soil Moisture

Reviewer 1 Comment: 5. Chapter "summary and results" is quite extensive. It should be shortened and focused on the main results of the paper

Author Response and Actions Taken: As described in the answer to comment 1: âĂć We focused on the validation and utility of CRNS method. âĂć We shortened the analysis on the relation between spatial variability and mean of soil moisture. âĂć We removed the analysis and discussion of the relations between spatial variability of soil moisture and ET These changes have reduced the overall length of the "Summary and Conclusions" section.

Reviewer 1 Comment: P3L18: Since the probe presented in this paper measures secondary fast neutron intensity above ground (and not cosmic-rays in general), it should called cosmic-ray neutron probe or in short CRNS.

Author Response and Actions Taken: We adopted the acronym CRNS (cosmic-ray neutron sensing) suggested by Reviewer 1 throughout the manuscript.

Reviewer 1 Comment: P4L7: This equation is not correct since it assumes that all storage changes are taking place within the effective sensing depth of the CRNS. Instead z should represent the depth of the root zone.

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Author Response and Actions Taken: Thank you for pointing this out. Since the application of the water balance equation (#6 in the new manuscript version) is made for storm event periods, ET is negligible and plant water uptake is not occurring. As a result, the use of z* instead of the plant rooting depth is justified. We clarified this point in Section 3.2 (page 13, lines 20-21). Note that we moved the water balance equation from the original location to the section on the CRNS water balance.

Reviewer 1 Comment: P4L18: Be more specific. Which spatial properties are you referring to?

Author Response and Actions Taken: Since we modified the "Introduction" to better focus the paper, this part is not present anymore in the paper.

Reviewer 1 Comment: P5L1-4: Recently Qu et al. (2015) demonstrated that variability of soil moisture can be explained by mean soil hydraulic parameters and their standard deviations in different ecosystems and climates. In addition this study showed that dry environments can also experience a decrease of SM variability in the wetter range.

Author Response and Actions Taken: Thank you for sharing this paper. We included a citation in the "Methods" section, page 13, line 1.

Reviewer 1 Comment: P5L8-10: The sensor network can provide both catchment scale average and spatial variability of soil moisture. Please explain why a combination of both techniques is still necessary for this kind of studies.

Author Response and Actions Taken: The relations between ET and soil moisture are usually studied using eddy covariance (EC) measurements of ET and soil moisture observations at single sites, or, less often, through networks of probes. An important advantage of the CRNS technique is that its measurement scale is comparable to the footprint of ET measurements based on the EC technique. Thus, in the paper, we compare the relations between ET and soil moisture based on the two methods for measuring soil moisture at different scales. This has been explained in the "Introduction" from page 4, line 20 to page 5, line 5. Since we removed the discussion of the effects of soil moisture variability on ET, we have also removed the line that this comment refers to.

Reviewer 1 Comment: P5L17: This study does not present a validation of CRNS in a strict sense, but rather a comparison with other methods. First, the soil moisture sensor network of both test sites is not well distributed within the CRNS footprint (the sensor networks do not cover well the CRNS foot and also do not consider the decreasing sensitivity of the CRNS with distance). Second, the water balance approach makes strong assumptions (e.g. CRNS measurement depth is assumed to be 40 cm). However, the actual sensing depth will strongly vary and given the variety in plant species of these ecosystems, the root zone is very heterogeneous and is not restricted to 40 cm everywhere. In addition, large parts of both test sites are not vegetated and which are only subject to evaporation. Here the soil depth that contributes to evaporation will be highly variable in time depending on SM content and soil properties.

Author Response and Actions Taken: We modified the assumption on the fixed CRNS measurement depth (z^* = 40 cm) and assumed a variable depth z^* for each event, as discussed in comment #3.

The sensor networks were designed to capture the spatial variability of soil moisture within each watershed, by accounting for the primary controls on the variability at each site (i.e. topography at JER and vegetation at Santa Rita - SRER). While the sensors are not distributed to the further reaches of the CRNS footprint, we applied averaging methods based on the spatial distributions of terrain at JER and of vegetation at SRER (see page 8, line 18 to page 9, line 2).

Specifically:

- At SRER, the soil moisture sensors were distributed under different vegetation cover. The differences in the soil moisture responses between diverse vegetation cover are larger than the horizontal spatial variability of soil moisture within the same vegetation

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class. So, we weighted the sensor network based on the amount of certain vegetation types, rather than on the distance to the CRNS sensor because this will provide a more accurate estimation of large-scale soil moisture.

- At JER, topography plays an important role in the soil moisture due to a more incised watershed. This results in soil moisture redistribution, as well as sharp differences based on aspect. We therefore weighted the sensor network based on an aspect-elevation relation presented in Templeton et al. (2014).

As a result, we believe that these soil moisture means are representative of the mean soil moisture state in the CRNS footprint. In this regard, the recent paper by Köhli et al. (2015) shows that the CRNS footprint is actually smaller than we originally thought, thus providing further confidence on the representativeness of our soil sensor networks.

Regarding the comment on the sensing depth, we recognize that a possible problem with our validation stems from the fact that we do not have soil moisture sensors in the topographic depressions caused by channels, leading to an overestimation of soil moisture by the CRNS method. This has been highlighted on page 16, lines 10-12.

We also added a comment explaining how the bare soil areas in the study watersheds are most likely also under the influence of plant transpiration as the desert shrubs and trees have expansive lateral roots extending into bare soil patches, see page 14, line 5-8.

Reviewer 1 Comment: P5L22: "evapotranspiration" instead of "root water uptake"

Author Response and Actions Taken: We have changed this word on page 5, line 14.

Reviewer 1 Comment: P5L22: The term "leakage" typically not used in vadose zone hydrology in this respect. The correct term would be "deep drainage" or "deep percolation".

Author Response and Actions Taken: We have changed this term to "percolation on

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page 5, line 14.

Reviewer 1 Comment: P6L8: Soil properties and topographic features of both sites need to be presented as well.

Author Response and Actions Taken: Soil properties are presented in page 6, lines 5-6 and page 6, lines 14-15 in the text and topographic features are presented in Table 1. We referenced a more detailed study of the site soils as Anderson (2013). We also added a new table 3 with more soil information.

Reviewer 1 Comment: P7L15: The watersheds are much smaller than the footprints of CRNS and EC. Please comment on why you believe that measurement still can be compared, especially in the light of soil heterogeneity.

Author Response and Actions Taken: While we acknowledge that the watersheds are in general smaller than the full extent of the EC and CRNS footprints, we also underline that:

âĂć The sizes of the watersheds are comparable or larger than the 50% contributing areas for each site shown in Fig. 2. âĂć The vegetation distribution does not significantly change at the scales of watersheds and footprints. In other words, it can be considered homogeneous at both scales, as also presented in Vivoni et al. (2014). This is stated in page 11, lines 13-15. âĂć Anderson (2013) performed a soil texture analysis in the footprint of the EC tower at both sites and found small variations, as stated on page 11, line 15. The paper by Kohli et al. (2015) shows that the footprint of the CRNS method is smaller than we originally thought, improving the representativeness of the watersheds for validation of the CRNS method.

Reviewer 1 Comment: P7L21: How many rain gauges were used in each site?

Author Response and Actions Taken: There were 4 rain gauges used at each site, as shown in Fig. 1. Since one of more of these gages reported different periods of malfunction, in the new manuscript version we indicated that we used up to four rain

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gages (page 7, line 12). Clearly, the Thiessen polygons used the estimate the mean areal precipitation were modified to reflect this.

Reviewer 1 Comment: P8L20-21: Statements in Campbell (1990) are not related to the measurement volume of the Hydra Probes used in this study.

Author Response and Actions Taken: Thank you, this is correct. It was our intention to cite Campbell (1990) in reference to the measurement of the impedance of an electric signal. The measurement volume is simply a physical characteristic of the sensor. We have modified the text on page 8, line 3 to reflect these changes.

Reviewer 1 Comment: P9L6-9: It is unclear why you are using different methods for each site. Please describe in more detail the reasoning behind the method selection. In addition, comment on why you are not accounting for the decreasing sensitivity of the CRNS with radial distance, like e.g. Bogena et al. (2013).

Author Response and Actions Taken: See answer to comment on P5L17 for justification of the different weighting methods at each site. We do not apply a method similar to that of Bogena et al. (2013) to weigh our sensor network because we focus our efforts on watershed-scale soil moisture. The sensor networks were installed to capture the variability and mean conditions within the watersheds. Another reason that we focus our weighting of the sensor network on the watershed is so that all three estimates of soil moisture (sensor network, CRNS method, and water balance calculation) are measuring the same control volume. We clarify this on page 8, line 19 to page 9, line 2.

Reviewer 1 Comment: P9L13: I thought the CRS-1000 was used in SRER.

Author Response and Actions Taken: The CRS-1000/B was used at both sites.

Reviewer 1 Comment: P9L21: The recent paper of Köhli et al. (2015) found different estimates for the CRNS footprint.

Author Response and Actions Taken: Thanks for your recommendation. In the new manuscript version, we have included the estimates from Kohli et al. (2015) (note that this paper was accepted after we submitted our manuscript). This is reflected in Fig. 2, and in the text on page 9, line 15.

Reviewer 1 Comment: P10L4: Eq. 2 gives gravimetric water content (see Bogena et al., 2013)

Author Response and Actions Taken: We performed a volumetric calibration, so that our No values reflect volumetric soil water. This implies that using neutron counts into this equation gives volumetric water content.

Reviewer 1 Comment: P10L13-17: Please give more information on the soil sampling (e.g. disturbed or undisturbed samples, dates etc.) as well as on the properties (e.g. mean values, standard deviations etc.).

Author Response and Actions Taken: The mean values with standard deviations of the bulk densities have been included on page 10, lines 17-21. The dates are presented in the caption to table 3.

Reviewer 1 Comment: P10L21: Please give more information on this method (e.g. how exactly rainfall periods have been ignored).

Author Response and Actions Taken: If we are correct, Reviewer 1's comment is referred to the boxcar filter method. We applied this rule: if rainfall events were large enough to increase the volumetric soil moisture by 6% or more, the boxcar filter was not applied. A line has been added on page 11, line 18-20 to clarify this.

Reviewer 1 Comment: P11L6: According to Templeton et al. (2014), the clay content at JER is 20.8%. Thus, lattice water needs to be accounted for at the JER site. Deviations between CRNS and in-situ SM at JER might be partly due to the false assumption of lattice water content.

Author Response and Actions Taken: A much more detailed classification of the soil properties was performed after Templeton et al. (2014) by Anderson (2013) and is

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used in this study. The new soil analysis included 60 samples throughout the site and found a clay content of 4.8%, therefore the assumptions of constant lattice water are justified.

Reviewer 1 Comment: P11L10-11: This is a very rough procedure. The horizontal weighing scheme of Bogena et al., 2013, should be applied instead.

Author Response and Actions Taken: When preparing this manuscript we considered a horizontal weighting scheme similar to that of Bogena et al. (2013), but we focused our weighting schemes on estimating the mean soil moisture in each watershed for several reasons:

1) The soil moisture sensors were installed to examine different processes at the two sites. At SRER, the soil moisture sensors were distributed under different vegetation cover. The differences in the soil moisture responses between diverse vegetation cover are larger than the horizontal spatial variability of soil moisture within the same vegetation class. So, we weighted the sensor network based on the amount of certain vegetation types, rather than distance to the CRNS sensor because this will provide a more accurate estimation of watershed-scale soil moisture. At JER, topography plays an important role in the soil moisture due to a more incised watershed. This results in soil moisture redistribution, as well as sharp differences based on aspect. We therefore weighted the sensor network based on an aspect-elevation relation presented in Templeton et al. (2014).

2) We wanted to use the watershed as our control volume so that we could compare soil moisture measured with the CRNS method, the point scale sensor network, and the calculation of the water balance.

3) As previously stated, one of the foci of this paper is to demonstrate the utility of the CRNS method to study and quantify hydrological processes. This was done through the application of the water balance that required the watersheds as control volumes.

Reviewer 1 Comment: P11L14-17: Please comment on possible influences of soil heterogeneity.

Author Response and Actions Taken: Please see our answer to comment P7L15.

Reviewer 1 Comment: P11L17: According to Köhli et al. (2015) the CRNS shows considerable variations in horizontal footprint size.

Author Response and Actions Taken: Thank you for pointing this out. The text has been updated on page 11, line 11-12.

Reviewer 1 Comment: P11L21: According to Templeton et al. (2014), the bulk soil density at JER is 1.37 g/cmˆ3

Author Response and Actions Taken: During the calibration of the CRNS sensor, we performed an analysis of the soil bulk density with a larger number of samples and found that the bulk density was 1.30 g/cm3, slightly different from Templeton et al. (2014).

Reviewer 1 Comment: P11L22: There are large differences in clay contents indicating differences in lattice water contents.

Author Response and Actions Taken: Please see our response to comment P11L6.

Reviewer 1 Comment: P12L5 and L17-18: Please present the temporal variations in z* for both sites and discuss implications for the soil water storage change estimations.

Author Response and Actions Taken: This is a good idea, thank you. Temporal variations in z* have been included in Fig. 3. The temporal variation in z* should have little effect on the comparison between the sensor network and the CRNS method, because the soil moisture from the sensor network were averaged through a method that accounted for differences in depth.

Reviewer 1 Comment: P12L20-22: According to results shown in Fig. 8 there is a considerable amount of deep drainage taking place at JER for several weeks during

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winter. What are the consequences of this violation of the “no-leakage” assumption?

Author Response and Actions Taken: As described in previous answers, in the new manuscript version, we have further explained the assumptions for the application of the water balance. Fig. 9 in the new version is referred to the application in continuous fashion of the water balance, where we have not made any assumptions on the leakage term. In fact, leakage can be obtained in this application as L = O – ET, when fCRNS is negative (i.e, water is leaving the soil depth z*). We also added a comment on page 20, lines 11-12, describing the winter time drainage and its link to precipitation events occurring when drought-deciduous plants are inactive since they lose their leaves and do not consume water through ET.

Reviewer 1 Comment: P13L5: Eq. 6 is not from Franz et al. (2012). Why are you using the minimum z*-value? Elsewhere you assume that z* equals z_m.

Author Response and Actions Taken: This approach was introduced by Franz et al. (2012b) without explicitly presenting the equation, which we deduced from the section “Cosmic-Ray Sensor Mass Balance”. The approach uses the minimum measurement depth between the two consecutive days, because we want to account for the water in the same layer of soil available for both days. Finally, as previously discussed, we have removed the use of z_m throughout the paper.

Reviewer 1 Comment: P13L7: I think it would be better to speak of “net” inflow and “net” outflow into/from the representative volume.

Author Response and Actions Taken: We agree with this suggestion and it has been incorporated in page 14, line 15 and line 19.

Reviewer 1 Comment: P13L11: Change into “. . .between soil domains above and below z*.”

Author Response and Actions Taken: The change has been made on page 14, line 20-21.

Reviewer 1 Comment: P13L16: The results of the soil sample analysis should to be presented in a Table (e.g. mean and std of grav. soil water content (SWC), soil density etc.). How did grav. SWC compare to sensor network SWC at both sites? How did grav. SWC compare to calibrated CRNS SWC at both sites?

Author Response and Actions Taken: We added a new table presenting the results of our soils analyses at both sites, including samples taken for calibration of the CRNS and for particle size analysis. Table 3 is now introduced in page 10, lines 16-18. We also added the available soil properties, such as porosity, bulk density and particle size distribution to the table for providing further details on the site soil characteristics.

Reviewer 1 Comment: P14L11-12: Please describe in more detail how you derived these analytical relationships.

Author Response and Actions Taken: We have removed these relationships in the new manuscript version.

Reviewer 1 Comment: P15L5-7: Differences of 3 to 6 Vol.% SWC are not large.

Author Response and Actions Taken: These differences between seasonal averages are significant if referred to these dry systems. Thus, we have added the word "relatively" to this line to highlight this point.

Reviewer 1 Comment: P15L11: Channels or linear structures are not visible in Fig. 1. What was the distance to a channel? Typically, water in channels shows very low effect on CRNS given their large measurement footprint.

Author Response and Actions Taken: The channels are generally quite small and rarely have flowing water. However, we are postulating that the topographic depressions in proximity of the channels remain wetter than hillslope areas after rainfall events. This assumption has been confirmed by one sensor placed in a channel at SRER, which reported consistently higher soil moisture values than the rest of the network (unfortunately, we do not have point scale sensors in or very near the channels at

JER). As a result, we attribute the lower values measured by the distributed sensors during the recession to the presence of wetter areas near the channels. To address this, we have added the text “and their associated zones of soil water convergence” to page 16, line 11.

Reviewer 1 Comment: P15L21: There is a huge scatter and even bias shown in Fig. 5. Therefore the term “excellent” is not appropriate.

Author Response and Actions Taken: We have changed this to “very good”.

Reviewer 1 Comment: P16L9-11: Is it really realistic that the soil completely dries out? Looking at Fig. 4 it becomes apparent that during very dry periods the statistical noise in the CRNS data (which is in the range of the SWC) produces values near zero which are clearly artefacts. In addition, the N0-method is not valid for SWC <0.2 (Desilets et al., 2010).

Author Response and Actions Taken: This line has been removed.

Reviewer 1 Comment: P16L11: What kind of limitations?

Author Response and Actions Taken: We meant limitations in measuring soil moisture at very dry levels. We have removed this sentence.

Reviewer 1 Comment: P17L9: Why should more homogenous soil lead to a shallower infiltration front? This should only influence the variability of the infiltration front. To support any discussion on influences of soil properties on hydrological processes, more detailed soil data of both catchments need to be provided.

Author Response and Actions Taken: Thank you for pointing this out. With this sentence, we were referring to the fact that there are less rocks in the soils at SRER. Thus, we changed “more homogeneous” into “less rocky”. We added more detailed soil information in a new Table (#3 in the revised manuscript).

Reviewer 1 Comment: P17L11: Undulated terrain typically promotes lateral water flow

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and not vertical water flow. Please explain why vertical flow is increased in JER by topography.

Author Response and Actions Taken: The undulated terrain can promote lateral flow to channel beds that typically have large sandy beds, which in turn promote vertical infiltration to deeper layers. This has been addressed on page 19, lines 3-4.

Reviewer 1 Comment: P17L16-18: Obviously the comparison between both sites is hampered by the non-average precipitation amounts in both. For an unbiased comparison longer time series would be needed to balance out any climatic anomalies.

Author Response and Actions Taken: We agree with this comment. Unfortunately, our records currently cover only 19 months.

Reviewer 1 Comment: P18L1: "more soil water" instead of "more ET"

Author Response and Actions Taken: Thank you for catching this. This has been changed to "produces more ET".

Reviewer 1 Comment: P18L7-9: Earlier you have stated that deep percolation at SRER is very limited (only few days).

Author Response and Actions Taken: We have clarified our use of the assumption of no leakage for calculating soil moisture using the water balance on page 14, lines 1-5. This assumption is only valid over the short timescale of a rain event and the rising limb of the soil moisture response. We are not assuming that there is never any deep percolation. Additionally, we believe that most of the deep percolation occurs near the channels where sediments are coarser and topography causes water to collect. This deep percolation in the channel is not detected by the deep sensor profile installed near the EC tower. We provide justification based on three sets of reasoning, on page 20, lines 13-17, but the primary one that applies to SRER is that we have one sensor profile installed in a channel and we see here that water commonly infiltrates past 30 cm depth.

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Reviewer 1 Comment: P20L12: The term “excellent” is not appropriate given the large differences

Author Response and Actions Taken: We changed to the term “suitable”.

Reviewer 1 Comment: P20L17-18: How do you come to this conclusion?

Author Response and Actions Taken: We come to this conclusion based on the fact that the relationships in Fig. 10 shows that ET-θCRS looks more realistic under dry conditions. The bare soil evaporation part of this function is well represented and shows a gradual increase with soil moisture. In the relationship between ET-θSN, this part of the function is too steep and does not represent the way bare soil evaporation changes with soil moisture. This has been discussed in page 21, line 15-19.

Reviewer 1 Comment: P20L21-22: But you stated earlier that the mesquite trees are extracting water below z*

Author Response and Actions Taken: We think that the two statements are not in contradiction. Higher soil moisture values sensed by CRNS within z* are still able to provide a larger ET due to extraction of water from the mesquite trees.

Reviewer 1 Comment: Fig. 1: Should be combined with Fig. 2

Author Response and Actions Taken: We believe that the amount of information presented in Fig. 1 and Fig. 2 deserves two separate figures.

Reviewer 1 Comment: Fig. 2: Why do you present the 50 % contributing areas of CRNS and EC?

Author Response and Actions Taken: The main reason that we used the 50% footprint is that larger footprints (i.e. 86% or 100%) for the EC tower and the CRNS sensor will extend well beyond the watershed domains, as could be discerned from Fig. 2. In addition, the 50% footprints fully contain the soil, terrain and vegetation layers available to characterize the sites and avoid large variations introduced by nearby channels

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outside of the sensor network sampling areas. Page 11, lines 9-11 have been updated to explain this.

Reviewer 1 Comment: Fig. 4: Please add calibration points.

Author Response and Actions Taken: The calibration was performed in February of 2013 for both sites, which is before our continuous study period so we cannot add those points to the figure. While CRNS operated prior to our study period, we began the comparisons on March 1 of 2013 because there was a malfunction in our eddy covariance tower during February of 2013. We now mention the calibration dates in the caption of new Table 3.

Reviewer 1 Comment: Table 2: Not important. Consider deletion.

Author Response and Actions Taken: We believe this table is important for the validation and comparison between fCRNS and the measured ET. We would like to provide quantitative evidence that the eddy covariance method is effectively capturing ET in order to have confidence in these measurements.

Reviewer 1 Comment: Table 3: Remove equations from the caption.

Author Response and Actions Taken: We removed the equations and added the reference Vivoni et al. (2008b) where the metrics are defined.

Reviewer 1 Comment: Table 4: Precipitation and ET were measured and should be listed separately

Author Response and Actions Taken: We changed "sensor estimates" into "sensor measurements" to reflect this.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 5343, 2015.