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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Multiscale soil moisture estimates using static and roving cosmic-ray soil moisture sensors" *by* David McJannet et al.

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RESPONSE TO REVIEWER 1 Responses included in text below...

Interactive comment on "Multiscale soil moisture estimates using static and roving cosmic-ray soil moisture sensors" by David McJannet et al.

Anonymous Referee #1

Received and published: 28 July 2017

The work presented by MacJannet and others investigates the use of mobile cosmic ray sensors for estimating soil moisture at a range of scales within a 36 km by 36 km area over an arid region in Australia. There are two regions of interest in the analysis,

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the 36 km x 36 km region aimed at producing 9km resolution soil moisture maps, and an inner region of 10 km x 10 km aimed at producing 1 km resolution soil moisture estimates. The authors highlight the importance of multi-scale soil moisture estimates for remote sensing validation as well as its use along with high-resolution land surface modeling.

The manuscript is concise and well written with clear steps. The figures are appropriate for the tasks taken and discussed in the manuscript. However, my main issue with this manuscript is its lack of novelty. The use of mobile cosmic-ray sensors (i.e., "rover") for soil moisture estimates is not new (as pointed out by the authors). The steps taken to convert the neutron counting rates from the rover to the final soil moisture is not new either. The regression analysis done to increase temporal resolution at gridded points within the region has also been done elsewhere. The manuscript reads very much like a technical report in which results are simply reported without much discussion. I don't see a clear scientific question being tackled in this manuscript. Perhaps, the only two pieces of relatively new information I noted were the updated relationship between lattice water and clay content particular applied to their region of interest (in comparison to a previous estimate from Australia) and the impact of number of integration points per area (which is directly related to the speed at which rover surveys are taken) on the quality of the soil moisture maps estimated from coarser to higher resolutions (but refer to my point about this below).

The authors made an important link to remote sensing soil moisture products and land surface modeling, and the manuscript feels a bit incomplete without a proper comparison against additional soil moisture "products". In addition, the authors claimed that the produced maps are "reliable" but how to assess reliability without an independent set of data? I strongly believe an independent set of data and comparison against model and remote sensing could have been an important addition to this manuscript and certainly contributing to its novelty. Unfortunately, I don't see a novel contribution that merits publication in HESS at this stage. My recommendation is for the authors

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to resubmit the work with a much clearer research question as well as incorporating of other independent soil moisture estimates to verify the impact of the rover soil moisture.

RESPONSE: We are currently preparing a manuscript comparing the rover surveys to sentinel satellite soil moisture retrievals and an Australian wide high resolution soil moisture modelling product. To include this comparison in this paper would make an extremely large paper. The paper is about establishing correct experimental design, developing new approaches to provision of spatial soil properties, nesting surveys to test resolution and survey design and exploring temporal stability in soil moisture across scales. We prefer to set out the approaches and novel findings here. The reliability in measurements comes from the calibration of the static and rover sensors and the fact that we can replicate the measurements across time. Unfortunately, there are no other 'scientific standard' measurements across this data poor location which is the whole purpose of proposing the rover surveys – the results here will be the basis of model/satellite validation and, hopefully, much better soil moisture information into the future but the first step is getting the rover experimental design, calibration and processing sorted which is what we have done in this paper. The testing across scales (fig 12) shows this.

We strongly believe there are enough contributions to make this a stand-alone paper. In response to the comment that this paper has no novel contribution we have to respectfully disagree. The novel contributions of this paper are:

1. We have develop a clay to lattice water relationship which is very strong. This growing data base of lattice water to clay relationships has also enabled us to produce a new lattice water product using the Australian Soil and Landscape Grid. This has potential application across Australia and internationally.

2. Our rover study is the first to use a digital soil mapping product to account for the spatial variation in soil properties across the survey area. This facilitate an easier set of data processing procedures and minimised assumptions that are made in other rover

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studies. This approach will be key to stream-lining the processing of spatial rover data in future surveys. This is a new approach to convert the neutron counting rates from the rover to the final soil moisture which can be applied to other gridded soil property databases.

3. We are the first study to use a nested high resolution survey within a larger broad scale survey. This approach has enabled us to test our experimental design in particular our selected driving speed and desired product resolution. This comparison has highlighted the need to design surveys fit for purpose and shows that different kriging models are required for different scale surveys as they are sensitive to different spatial information.

4. We have further demonstrated that N0 for static probes is strongly controlled by biomass. Our two static sites with different soil type and moisture have essentially the same N0 as the respective footprints are essentially biomass free. This is very useful information for rover surveys in this region and points to a standard N0 if biomass is accounted for in calibration and spatial variation in incoming neutron intensity can be correctly accounted for.

5. We have provided evidence for temporal stability in soil moisture in this dry land setting. We demonstrate this at the property scale (most relevant to farm managers) and this has great relevance to local land holders who can relate their property to neighbouring sensors, and scientists who can use point-to-area scaling to fill the gaps between rover surveys for comparison to other soil moisture products. These points will all be described in our modified discussion section.

Additional specific comments:

1. Eq. 5: Please, explain what W_lat, W_SOC, and rho_bd are right after the equation is presented. I believe rho_bd is never described properly in the text.

RESPONSE: Will be fixed as suggested and rho_bd description will be added

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2. Section 2.3: It might be a good idea for the authors to show a picture of the rover system in this section.

RESPONSE: We have pictures on our cosmoz website (http://cosmoz.csiro.au/about-cosmoz/) so we will add a link to these rather than making the manuscript any larger

3. Section 3.1: I believe Fig 4 is meant to be mentioned in this section (but it is not currently)

RESPONSE: Fixed

4. Section 3.3: I believe Fig 5 is meant to be mentioned in this section (but it is not currently)

RESPONSE: Fixed

5. Section 3.4 and 3.5: The authors assume the reader has good knowledge of spatial statistics and how the fields are ultimately interpolated to produce soil moisture maps. For example, the discussion about “sill” may not be clear to the broad readership of HESS. In fact, what does having or not having a “sill” imply? What does “sill” represent in this case (from a physical soil moisture variability context)? The authors should also highlight the sill parameter in the plots presented in Fig 6.

RESPONSE: The concept of the sill and what it means for spatial statistics will be added to section 3.4. The meaning of the sill and range in the context of spatial interpolation will be added. The sill and range will be labelled in fig 6 to aid interpretation as suggested by the reviewer

6. Section 3.5: Ideally, one (including myself) would like to see the soil moisture maps compared against independent measurements. It is expected that the map-derived soil moisture will compare well with the two static sites since the rover was calibrated using the same data. So, the whole approach appears a bit “circular” to me. At the end of this section, the authors make a good point about the importance of these measurements form model testing and remote sensing. I strongly recommend the authors to expand

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their manuscript to include comparison against remote sensing and land surface mode and discuss reasons for similarities and differences.

RESPONSE: Unfortunately there are no other 'scientific standard' measurements across this data poor location so this comparison is not possible. In addition many points would be required due the very high variability in soil moisture often exhibited at point measurement scale and our desire to compare to a large scale rover product. We acknowledge that there may appear to be some circularity but we are not comparing the non-moving rover to the static sensors – this is the final interpolated soil moisture product using the soil grid properties and conventional kriging of neutron counts. We are testing the whole calculation procedure and underlying data (i.e. soil properties) here. We are comparing to static sensor which uses locally measured soil properties. The results here would only be expected to be this good if the spatial interpolation models used were accurate. Comparison to remote sensing and model estimates is in preparation – too much to cover in this paper as well.

7. L290-302: There is some potentially interesting analysis here but I also wonder if the results can be strongly influence by the soil properties themselves. In other words, if the authors apply the same comparison between the broad survey and intensive survey using the soil properties (not the estimated soil moisture), would they see a similar behavior? How much of the difference in soil moisture they currently observed is conditioned to the soil properties versus the changes in resolution due to averaging? Also, how can the authors justify comparing measurements, despite being originally taken at different resolution, that essentially come from the same methodology, instrument, and calibration against the same data? This appears a bit weak to me and reinforces my point about differences due to variation in soil properties.

RESPONSE: We cannot produce the same plots of difference (as with soil moisture, i.e. Fig12) as the same underlying soil property data is used from the Australian soil and Landscape grid for both surveys and its resolution is 90 m. The differences between surveys observed in Fig 12 are purely those related to differences in neutron counts in

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both surveys which were observed at very different speed. The broad survey is moving so fast the small scale detail is smoothed out hence the difference at the 1 km and 3km scale but none at 9km scale. We justify comparing the measurements as we are demonstrating the importance of selecting the appropriate drive speed depending on the final product resolution required. We show that the speeds used for the broad scale survey are not suitable for soil moisture estimates at resolutions of 1 km and 3 km. We only get agreement between the two products when the resolution is set at 9km – i.e. the design speed has been successfully set.

8. L329-342: Interesting discussion about the road effect. It can definitely influence the results but I'd expect such influence to be more pronounced in humid sites (and not so much at arid sites)??? Also, because the maps (broad and intensive surveys) are derived from the same approach, any road effect may actually be cancelled out when comparing both surveys.

RESPONSE: The issues of road influences is definitely an interesting one and is something future surveys should take into account. I am aware of some researchers who are working on a solution to this issue (not published yet) and as you say this will be particularly useful in wetter/more humid areas. To push this fact further more text will be added to highlight that the dry road will be over represented in the measured neutron intensity as the sensitivity to hydrogen of neutron intensity is greater at the dry end.

9. Table 1: Please, add a column with footprint-average soil moisture conditions for each case

RESPONSE: This information will be added to Table 1

10. Figure 7: These maps are interesting but they should be evaluated with other points (any points available within the domain) that had not been directly used to calibrate the rover itself. Otherwise, the only information in those maps are potentially the relative differences between wet and dry areas. Similar comment applies to Figs 9, 10, and 11.

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RESPONSE: There are unfortunately no other completely independent points in the domain which can be used for evaluation of soil moisture estimates. The point of the figure is to show the relative differences in the domain and to show the ability of the rover to observe these. We discuss how these patterns relate to soil properties which of course reflects differences in soil moisture (i.e. sand v clay).

11. Figure 8: The results here are expected and my only interpretation here is that the characteristics of soil moisture at 1km resolution (obtained with the rover) are comparable to finer scale from the static sensor (i.e., there may not be large differences between the 200-300m integrated soil moisture compared to the 1km resolution product).

RESPONSE: The results here would only be expected to be this good if the spatial interpolation models used were accurate. We are not comparing the non-moving rover to the static sensors – this is the final interpolated soil moisture product using the soil grid properties and conventional kriging of neutron counts. We are comparing to static sensor which uses locally measured soil properties.

12. Figure 12: For all soil property maps in the domain (W_lat, W_SOC, rho_bd), can the authors reproduce the same plots? In other words, averages at 1km, 3km, and 9km within the overlapped area for broad and intensive surveys. Can the results tell authors what possible controlling factors are associated with the differences between both surveys? I believe this can initially be expanded to something interesting and novel.

RESPONSE: As for comment 7 above - We cannot produce the same plots of difference (as with soil moisture, i.e. Fig12) as the same underlying soil property data is used from the Australian soil and Landscape grid for both surveys and its resolution is 90 m. The differences observed in Fig 12 are purely those related to differences in neutron counts in both surveys which were observed at very different speed. The broad survey is moving so fast the small scale detail is smoothed out hence the difference at the 1 km and 3km scale but none at 9km scale.

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