Response to Anonymous Referee #1

We would like to thank Anonymous Referee #1 for their positive review of our paper. We are hereby providing responses to their major comments / questions, whereas editorial issues will be addressed in the revised manuscript.

The authors present 3 methods for estimating root zone soil moisture storage from a cosmic-ray probe at a well instrumented study site in Saskatchewan. This is the first attempt to assimilate CRP data to provide the critical root zone product that the scientific community desires. While this is a common problem in remote sensing this is a novel and needed study for continuing to advance the CRP methodology. The authors find good agreement with the 3 methods with the most promising one being the exponential filter for transferring to other less instrumented field sites. The paper is well written and appropriate for HESS following minor changes.

Minor Comments:

P12795 L7-14. The authors chose to use a single calibration period to estimate the free N_0 parameter. In addition, 4 more calibration efforts were used to validate the CRP values. More recent work (c.f. Iwema 2015) suggests ~3 calibration periods at different VWC to effectively calibrate a probe. While not critical here given the good agreement, using 3 calibration samples to estimate N0 might further reduce any bias in the CRP vs. the "true" area average VWC. The Iwema 2015 article should be included in the citations and some discussion on using a few calibration samples to estimate N_0 could be included.

> Response: Thanks for bringing this to our attention. We have subsequently explored the possibility of including measurements from one or two of the validation periods into the calibration exercise. However, while addressing suggestions from Referees #2 and #3, we updated the CRNP soil moisture equation to include lattice water, soil organic matter, and have weighted both the calibration and validation samples based on proximity to the probe using the function given by Köhli et al. (2015). The new CRNP soil moisture equation, calibrated based on the single calibration point, now provides an even better fit to the validation points. Although Iwema et al. (2015) suggests three calibration points may be desirable, they also mention that in a semi-arid region only a single calibration point may be necessary. In our case, given the improved fit with the updated equation, we feel that there would be little benefit to adding additional calibration points (at the expense of removing validation points). The updated calibration curves have been plotted in Figure AC 3-1 (which is included in the author response to reviewer #3).

P12805 L21-25. This is a key point about the CRP vs. other remote sensing with shallower penetration depths (< 2 cm). My feeling is the depth of the CRP at >10–15 cm captures the

entire evaporation front and therefore a majority of the latent energy flux in sparsely vegetated areas (like grasslands). This is key for accurately assimilating the signal to provide an accurate root zone product. This point could be better highlighted in the conclusions. While this depth only accounted for 40% of the seasonal changes (although I have my opinion that the effective CRP depth may be deeper than first believed because of the revised moderated detector energy bins, Kohli 2015 WRR, McJannet 2014 WRR, unpublished MCNPx simulations and unpublished SWE measurements), this still likely captures the evaporation component of latent energy flux. Not sure what the E vs. T ratio for this grassland is but imagine fairly high in E vs. T.

> Response: This is a good point. From the perspective of assimilating soil moisture into models, the CRNP likely provides a considerable advantage over shallower remote sensing techniques. This is something that we plan to investigate in future work, but we don't currently have any results to suggest what measurement depth is most appropriately assimilated for this environment. We will include a statement about the potential for assimilating CRNP data in the conclusions of the revised paper.

P12808 L 6-10. I feel that instruments like electromagnetic induction or GPR could help resolve some of the spatial patterns of texture variability and vertical structuring at a CRP site to then run an exponential filter. A reconnaissance style survey would then help constrain the exponential filter model without a need for detailed soil surveys or widespread destructive sampling. The idea of joint methods in hydrogeophysics coupled with physical models is an exciting and emerging area within the hydrogeophysical community (Binley 2015 WWR, "The emergence of hydrogeophysics for improved understanding of subsurface processes over multiple scales"). No action items, just more of a comment.

> Comment: Thanks for suggesting this interesting approach for parameterizing the exponential filter. A technique that could provide insight regarding textural variability and vertical structure could likely greatly improve the portability of the exponential filter method, and reduce the learning/calibration period.

REFERENCES:

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