Response to Anonymous Referee #2

We would like to thank Anonymous Referee #2 for their review of our paper. The responses to his/her substantive comments are provided below, whereas items of a purely editorial nature will be addressed in a revised version of the manuscript.

This paper describes approaches for estimating soil moisture through the entire root zone at a field scale using surface soil moisture measurements from a cosmic-ray probe and 3 different depth scaling approaches. This subject will be of great interest to many researchers working on similar problems and has applications further than the cosmic-ray probe to other near surface measurements. The exponential approach clearly has advantages in terms of required instrumentation and the ability to make root zone soil moisture estimates at the same time resolution as the cosmic-ray probe estimates. The paper is well written and I recommend only minor changes before I believe it is ready for publication in HESS.

Section 2.2.1 – there seems to be no adjustment for soil organic matter or lattice water which represent an additional pool of hydrogen. Depending on the size of these pools they can have an effect on the fit of the universal curve (see Hawdon et al. 2014 and Zreda et al 2012) and hence impact upon derived soil moisture estimates.

> Response: Thanks for suggesting this. We have subsequently examined the impact of including the hydrogen pools associated with the lattice water and the soil organic matter as per the equations in Hawdon et al. (2014). The use of the updated equation for calculating volumetric water content provides a much better match to the validation samples. For the effective measurement depth, the inclusion of lattice water means even shallower measurements. The average measurement depth of the CRNP is now 14 cm. The updated calibration curves have been plotted in Figure AC 3-1 (which is included in the author response to reviewer #3).

Section 2.3.2 – how do you deal with varying measurement depth of the CRP in such a scheme?

> Response: We regret not articulating this more clearly in the original text. The spatial average water content, which all methods are compared against, is calculated from the CRNP signal (integrated over the time varying CRNP measurement depth) and combined with the neutron probe readings below this. The shallowest neutron probe reading is at 20 cm, and this is assumed to represent the water content from below the CRNP measurement depth to 30 cm depth. For all other methods, we assume the CRNP is measuring to the same depth each day. The average measurement depth of 14 cm is used. We will clarify this in the revised version.

Section 3.1 – While agreement between validation and CRP estimates is good not including lattice water or soil organic matter could also account for the differences you see. Similar underestimation at low soil moisture and over estimation in wetter conditions is shown in Hawdon et al 2014 when these hydrogen pools are ignored (see fig 9).

Response: We have subsequently updated our analysis to include lattice water and soil organic matter, which has improved our estimation of soil moisture and we now have better agreement with the validation measurement. The updated calibration curves, and the fit of the validation points, have been plotted in Figure AC 3-1 (which is included in the author response to reviewer #3).

REFERENCES:

Hawdon, A., McJannet, D., and Wallace, J.: Calibration and correction procedures for cosmic-ray neutron soil moisture probes located across Australia, Water Resour. Res., 50, 5029-5043, doi:10.1002/2013WR015138, 2014.

Zreda, M., Shuttleworth, W. J., Zeng, X., Zweck, C., Desilets, D., Franz, T., and Rosolem, R.: COSMOS: the COsmic-ray Soil Moisture Observing System, Hydrol. Earth Syst. Sci., 16, 4079–4099, doi:10.5194/hess-16-4079-2012, 2012.