Response to detailed points of reviewer #1

A revised manuscript will account for the 36 specific comments and suggestions. Most of them will be done as suggested. The others are discussed or questions answered in the following.

Page 3, line 82. Interesting thought. It is mere coincidence the value for a* is close to exp(-1), at least we see no physical reason how it could not be. The three a-parameters needed to calculate a* include implicitly a mix of some physical constants, but rather a diverse set of neutron scattering and absorption properties, which are not likely just to cancel out each besides exp(-1). Also, a* is different to exp(-1) already the second digit after the decimal, which is more than round-off errors as the a-parameters have been provided for the Desilets equation to three digits after the decimal.

Page 3, line 82. In the manuscript new parameters such as a* or N_bg are consequently shown as formula based on existing parameters, but also a value is provided to provide a notion of their magnitude (e. g. being smaller or larger than 1) and enable readers to use them for calculation. These values have been specified with 5 digits after the decimal to keep rounding errors minimal, as the a-parameters have been provided for the Desilets equation to three digits after the decimal. This is not meant to imply a higher level of significance, but at least one digit more then the input parameters will be kept to avoid unnecessary rounding error.

Page 3, line 84. Will be reformulated, as the mathematical procedure will be changed (see also comment on page 4, line 127). Also we will provide an expression how additional hydrogen pools can be used to define a local N_max value closer to the local (corrected) neutron count rates.

Page 3, line 92. Will be rephrased, only the word “than” was missing before N_max, as N_max > N_0 mathematically.

Page 3, line 100. We will follow the suggestion of the reviewer and rename N_bg to N_min.

Page 4, line 127. Thanks for checking the sign in eq. 3d. And yes, these terms influence also indirectly a*. This was not accounted for in deriving this particular equation with a modified a_2. This will be corrected in a revised version. It should be noted that this equation was meant for an alternative situation only, that is for explicitly including additional hydrogen pools, but was not used in the further development. But thanks again to the reviewer.

Page 4, line 132. Will be changed to ‘which have minimal values around zero’ for clarification.

Page 5, line 151. Corrected neutron count rates would be even smaller for fully saturated conditions at a site if the porosity and thus water content was larger (or water is ponding on top of a saturated soil). We will quantify this difference in a revised version of the manuscript and give the minimal count rate at fully saturated conditions an own name (N_min,local).

Page 5, line 158. This is an assumption based on practical experience. To provide an extreme example: If the snow height is starting to reach the CRNS device it will certainly reduce neutron count rates further as blocking (some) pathways of neutrons through the air that otherwise would reach the detector. But as the manuscript is not about snow influence, the statement could be changed to be neutral, just saying that presence of snow is not accounted for.

Page 5, line 181. In this example how the derived equations could be used for a low-level calibration the value of the new calibration parameter (N_bg, N_max or (N_max-N_bg)-window) was fitted manually. This is on purpose, as adjusting the gap size between corrected neutron count rates and these boundaries allows a user to introduce soft information on the site. For example, a peatland site with extremely high water content values when saturated (larger than 70-80 % volumetric water content) will have a N_bg close to the minimum corrected neutron count rates (see Rhinluch example), but other sites will have a larger gap, especially at the more sensitive dry end. However, we will define a closer local N_min and N_max value based on values of bulk density, lattice water and soil organic matter content, as additional hard info. Furthermore, a revised manuscript will provide an additional diagram showing how these new calibration parameter (N_bg, N_max or (N_max-N_bg)-window) look like for a corrected neutron count rate time series based on an already calibrated N_0 value.

Page 6, line 213-214. Here we argue that the usual approach of quantifying the statistical error as square root of the absolute number of neutron counts (cumulated during the integration period) is not accounting for that the true range of corrected neutron count rates is smaller and thus the absolute statistical Poisson error is smaller. In other word, a constant background value does not contribute to the statistical error. And for CRNS we have a substantial constant background (or minimal) count rate and thus should account for that. However, as the relative error for a Poisson distribution is sqrt(N)/N we should not neglect that also the denominator has to be modified to a lower value. The following eq. 7 shows quantitatively how the statistical error in water content derived by CRNS results from the statistical error in N_c.

Page 7, line 220-221. Simply said, the statistical error in gravimetric water content, i.e. the second summand on the right hand side of eq. (7), depends on N_bg, and as N_bg >> 0 this should make a difference.

Page 12, line 404. Okay, this statement is not based on a full scale market analysis, but rather on personal experience, however, with n > 10. But to give some values, 11 years ago the prize for a single Hydroinnova CRS1000 with moderated detector was 17 800 USD, in the version with additional bare counter even 26 100 USD (according to a quote to us). These were probably the most common CRNS devices at that time. Nowadays, for some time, StyX Neutronica states on their webpage that their CRNS probes 'S1' with a typical count rate per hour of 1000 are 'starting from 6800.00 €' (accessed last time at 16/March/2025). Thus, a CRNS device with similar sensitivity to the common Hydroinnova CRS1000 has now a prize of less than half of the latter. This supports the statement in the manuscript, but as the statement in the manuscript is not rectifying to add an additional paragraph to the manuscript, we will rather soften the statement in the revised manuscript.

Page 12, line 414. No, sites to be monitored do not have to have surface water bodies close by. But if a site has, this could be exploited for a such a direct calibration before moving the CRNS device to the monitoring position at the site; or to move a CRNS device at the end of a monitoring period to such a surface water body at the site, before taking it away, especially if a local soil moisture sampling campaign for calibration has not been performed for whatever reason.

Page 12, line 420-422. We will rephrase the note to be less ambiguous and concentrate on what can be deduced more clearly. The soft direct calibration approach outlined in the manuscript is meant as a last resort if a full-scale standard calibration has not been feasible and in almost all cases a full-scale standard calibration will be more accurate and trustworthy and has to outperform a low-level direct calibration. Instead of such an unsurprising comparison a revised manuscript will provide an additional diagram showing how the new calibration parameters (N_bg, N_max or (N_max-N_bg)-window) for a corrected neutron count rate time series example based on an already calibrated N_0 value.

Page 12, line 426. We will rephrase the statement. Nevertheless, to give a (real) example. If one brings a Hydroinnova CRNS from a low mountain range location in Germany to a high-altitude site in the Austrian Alps, the neutron count rates will almost triple. If one would continue to use the N0 value calibrated at the former site now at the new site, the calculated soil moisture would be extremely off, towards the very dry end. This is what is meant with ‘not having a calibration at all’. Such an example can be included, though it is rather obvious that a direct calibration could do better than that.