Review on “Influence of Snow Spatial Variability on Cosmic Ray Neutron SWE” by Kim et al.

The study of Kim et al. on the “Influence of Snow Spatial Variability on Cosmic Ray Neutron SWE” evaluates in a comprehensive analysis the effect of snow distribution on the signal of a cosmic ray neutron sensor at an agricultural prairie site in Montana. The authors apply a threefold analysis to find general recommendations on the position of a CRNS probe for area-representative measurements. In a first approach the effect of snow cover is tested in Neutron Simulations under homogeneous and heterogeneous snow conditions. A second step compares the area-representativeness of CRNS to virtual snow scale/pillow observations with a smaller footprint. Finally, the CRNS-derived SWE signal is compared to daily satellite-based SWE products. The limited amount of studies on above-snow CRNS and the need for area-average SWE observations for remote sensing product calibration and integration make this study very valuable.

General comments

The outline of the manuscript is well structured and easy to follow. By testing the effect of snow cover on different virtual CRNS sensor locations, the authors find that the in-field CRNS sensor is located at an area-representative location, before evaluating satellite-based SWE observations against the CRNS-derived SWE measurements. By calibrating the SWE conversion with a snow free reference value (15 January), the pre-snow moisture level of the site is considered. However, two major points require reconsideration: 1) The effect of partial snow cover has been noted in line 89-90, and addressed in line 314 to 332 (with SCA ranging from 1.8 % to 89.6 %). Partial snow cover does not seem to affect the NC signal in this study. Since this finding is contrary to previous studies, the results of the correlation analysis should be shown and addressed in more detail. The lacking indication of snow-free areas in the snow cover maps provides the impression of a closed snow cover (see comments on figure 3) and misses that the footprint of many virtual sensors is only partially snow covered or snow-free. 2) Line 260 to 263 note boundary effects in the URANOS model, but section 3.2 does not specify the boundary conditions that were chosen. For clarity, the study should provide further information and the distance between the outer virtual sensors and the boundaries of the URANOS domain.

Minor comments

- The title should indicate that the analysis covers a case-study in a prairie environment.
- The major outcome that is outlined in the abstract from line 17 to 20 should not be indicated as a logical consequence. It rather seems that study 4.1 shows that CRNS is influenced by snow drifts and study 4.2 shows that an area average can be obtained by placing a sensor in the proximity of a snow drift. However, figure 8 c) and d) shows that an area average may also be obtained in a location afar from snow drifts, meaning that both findings are true, but don´t condition each other.
- Line 186-188: It is acceptable to use a constant footprint size, but the footprint dependency on the amount of present moisture (i.e. snow) should be briefly discussed.
- Analysis 4.1 distinguishes between uniform snow thickness scenarios, computed from the SWE average of the CRNS footprint and the SWE average of the study domain. In the sub-studies, outlined from line 240 to 283, it becomes not clear, which of the two scenarios have been used.
- The results and discussions around Figure 4 and 5 seem straight forward. However, it is questionable if the “snow-free” day is a good choice for an analysis of the effect of snow cover. If the SWE average is based on the CRNS footprint in this analysis, almost all virtual detector locations are compared under completely snow-free conditions, except for the sensors close to the remaining snow patch (“snow drift”). Choosing a day with a more prominent snow cover (e.g. 17 February) would be more relevant.
- Results and discussions around Figure 6 and 7 would benefit from additional information on how much each virtual detector was affected by fractional snow cover throughout the study. This would strengthen the discussion, which seems to evaluate the complexity of snow cover within the footprint area from visual inspection.
- The analysis of section 4.2 and 4.3 give a great added value to the study. While results of 4.2 are partially mentioned in the abstract (l. 20-22) and a hint on 4.3 is provided in the introduction (l. 94-95) they appear hidden and should be more clearly visible, in both abstract and introduction.
- The analysis in 4.1 shows that CRNS measurements on the “snow-off” day (January 15) were affected by the snow drift, presumably lowering the N_θ that was chosen for the SWE conversion. The effect on the converted SWE signal should be briefly discussed in 4.3.
- Consider rephrasing line 480 to 482 for better logical reasoning and more clarity.

Illustration remarks

- Figure 1:
  - For clarity, the position and viewing direction of these images could be marked in Figure 2.
- Figure 3:
  - A different color should be applied to snow-free areas to allow for a differentiation into areas of heterogeneous snow cover and areas of partial snow cover.
  - The choice of an exponential color scale is reasonable, but should be better indicated in the legend (e.g. color bar with exponential color distribution, instead of even increments)
  - The images miss a scale bar. A dashed line that indicates the domain outline as in Figure 2 would be additionally interesting, as well as the distance of the outer virtual detector locations to the domain boundary.
- Figure 5:
  - For consistency, the color scale in e) to f) should be the same as in the previous figures (white indicating low snow and blue indicating high snow accumulation). Further, the SD maps miss a scale bar.
  - Since the findings at P00 and P19 are contrary (larger changes on the snow side) to the findings at P07 and P05 (larger changes on the no-snow side) besides the similarity in snow distribution, P19 should also be presented in this figure.
- Figure 6 & 7:
  - The figure should indicate which scenarios were included in the analysis (all except 15 January).
  - Coloring the scatter plot after the snow cover fraction within the corresponding virtual detector footprint may add valuable insights.
- Figure 8:
  - The choice of red as a color for agreement seems counter intuitive. Green may be a better choice (the significance of that color needs to be indicated in the legend).
  - All maps miss a scale bar.
  - The exponential character of the SWE color bar should be displayed with exponential color increments.