Dear Editor,

We sincerely thank the two referees for reviewing our manuscript and the positive evaluation of the revised manuscript.

We have considered the major and minor points of Referee #1 and added some further information on the daily fluctuations of the measurements in the manuscript and the supplement.

Please find a detailed point-by-point answer to the referee's comments below.

Yours sincerely,
Rebecca Gugerli on behalf of all authors

Referee #1 – Authors reply

In the following, we provide a point-to-point answer to the referee's comments. The referee's comments start with RC:*, authors replies begin with AR: and are formatted italic with light-blue color.*

A markup of manuscript changes are shown in boxes with new text in dark blue and ~~removed text in red.~~

RC: Thanks to authors for the clear and concise reply. The paper definitely improved. However, I still miss one important point, which I believe needs to be discussed, before acceptance.

AR: We thank the Referee #1 for the time dedicated to our revised manuscript, and the positive and constructive feedback to our changes.

RC: My original remark "Even neglecting the large fluctuation in February, the daily signal (for the μ-CRSG and n-CRSG) often demonstrates strong negative changes during the accumulation season (e.g. April)" has not been addressed properly. You now just assume that the frequent decreases in SWE are caused by snow erosion without any further analysis. I would at least expect that you check if periods with clearly decreasing SWE (Fig. 3b) correlate with high wind speed and concurrent decreasing snow depth. If not, the decreasing SWE values must be caused by something else. It might be related to the two-part conversion function, because the unexpected SWE decreases only happen above 1000 mm SWE!

AR: Thank you for this comment. We apologize for not having been clear about our assumptions of the SWE decreases. There are certainly many effects that may explain these inter-daily fluctuations.

In general, the change in SWE from a day to another (inter-daily fluctuation) can be related to changes of the snowpack as well as influences by the cosmic ray fluxes and/or the conversion function. Environmental conditions, which cause snow drift, deposition and/or sublimation, may lead to increasing or decreasing amounts of SWE. In addition, the statistical variability in the count rates becomes more important with increasing SWE.

We included some further analysis for the inter-daily fluctuations and added the results to the manuscript in Section 4.1. An additional analysis with daily maximum wind speeds was added to the supplement in a new section and referenced in the manuscript.

[Section 4.1.]

Generally, the hourly SWE observations by the μ-CRSG ~~has~~ have less variability throughout the day than hourly SWE observations by the n-CRSG as their spread around daily averages is lower (Fig. 3b). Nonetheless, daily μ-CRSG SWE ~~fluctuates more in February compared to the~~ show larger changes between days compared to n-CRSG SWE ~~Two~~ for SWE larger 1000 mm w.e. The inter-daily fluctuations in February 2021 could be related to two major Sahara dust events (5-6 Feb 2021 and 22-25 Feb 2021, MeteoSchweiz, 2021)~~could be related to these fluctuations~~, but this remains speculative. ~~Apart from this period, the temporal fluctuations are consistent between~~ More quantitatively, daily changes in SWE, i.e. the difference between the daily mean SWE of day 1 and day 0, show a correlation of 0.64 between the n-CRSG and μ-CRSG ~~SWE~~(Figure S3a). Daily decreases of SWE before the onset of snow melt (beginning of June 2021) may be related to snow erosion. However, an analysis with daily maximum wind speeds did not show conclusive results (see supplement). Noise within the muon count measurements, the two-part conversion function, and/or production and decay processes within the snowpack that may affect the top µ-CRSG differently than the sub-snow one may influence daily changes within the SWE observations by the µ-CRSG. Further investigations including simulations of cosmic-ray muon production and decay are required to analyze and quantify these influences. Such investigations, however, are beyond the scope of this work.

[Supplement: Section 4 Daily fluctuations analyzed with maximum daily wind speed]

Hourly wind speed is measured at the station on the Glacier de la Plaine Morte from 20 October 2016 to 13 August 2021. The n-CRSG measurements in a deep snowpack are limited in their temporal resolution due to the counting rate statistics at this site. Hence, the following analysis is based on daily measurements.

Inter-daily fluctuations of n-CRSG and µ-CRSG correspond to the difference of the daily mean SWE from day 1 to day 0. If the change is positive (negative), an increase (decrease) in SWE is observed. Figure S3a shows the correlation between daily changes of n-CRSG and µ-CRSG.

Daily maximum wind speed is derived from hourly measurements of maximum wind speed. From 16 December 2020 to 13 August 2021, 238 days of daily maximum wind speed observations are available. On average, the daily maximum wind speed is 10.0±3.9 ms^{-1}

Figure S3b shows a statistical summary of these daily differences as a function of maximum daily wind speed bins. If the daily maximum wind speed is lower 10 ms^{-1}, no change or a minimal decrease in SWE is observed by both CRSG's. For wind speeds higher 14 ms^{-1}, both devices show more days with increasing SWE amounts. Almost 80% of days with maximum wind speeds higher 14 ms^{-1} occur from December 2020 to April 2021. Please note that snow drift is not only a function of wind speed, but also of the snow density of the top layer of the snowpack. With our measurement setup, however, we have no means of deriving a reliable snow density of the affected snow layer. With snow depth, only a bulk snow density can be derived.

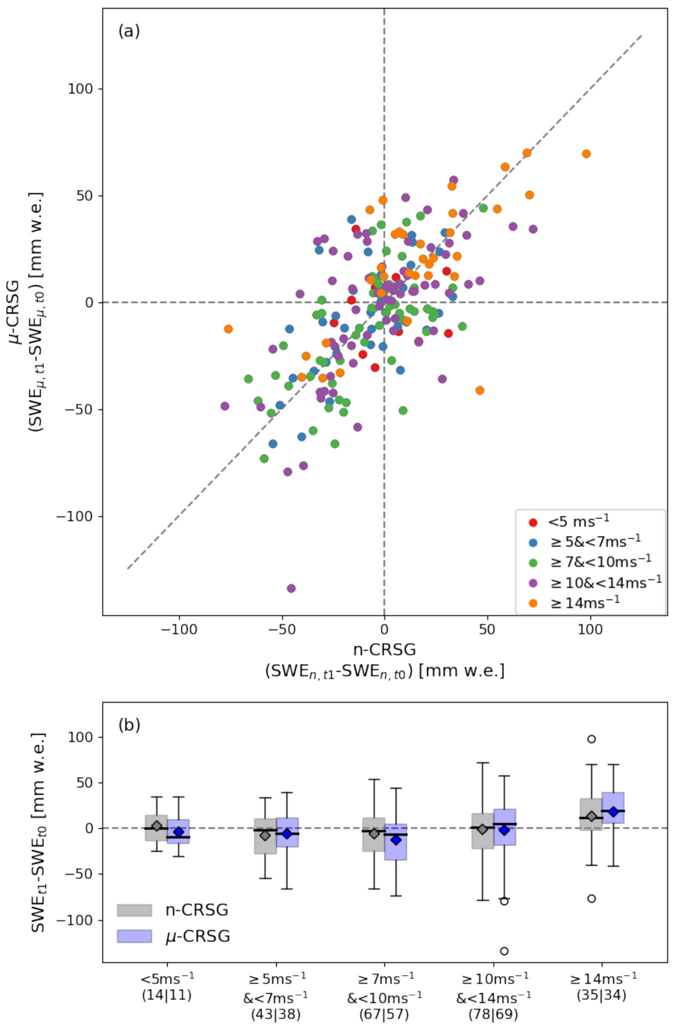

Figure S3: Daily changes in SWE are related to the daily maximum wind speed measured at the site. Panel (a) shows correlation between the daily fluctuations of the n-CRSG (x-axis) and the mu-CRSG (y-axis) with various wind speed bins in colors. Panel (b) shows the statistical summary of these daily fluctuations as a function of wind speed of the n-CRSG (grey) and the mu-CRSG (blue). Diamonds represent the mean and the solid black lines show the median value. The numbers in the legend represent the number of days included in this analysis for the n-CRSG and mu-CRSG, respectively. These may differ according to the available measurements of the n-CRSG and mu-CRSG.

RC: Otherwise, I only have few minor points, which I'd like to have been addressed before publication:

RC: L 58 & 61: It's the ultra-sonic snow depth sensor, because there is only one at the station.

AR: We adapted the sentence as follows.

SWE is calculated by multiplying the manually-obtained average bulk snow density with the autonomous and undisturbed daily snow depth observations by the ~~an~~ ultra sonic ranger installed at the station.

RC: L186: Please provide the length of the short tube as “short” is a relative measure.

The manual snow observations are based on two main approaches; short tube (55 cm long) samplings within snow pits and snow core samplings.

RC: L200: As the MeteoSwiss report is in German and only addresses the first event, I’d suggest to use the following reference: https://hal.archives-ouvertes.fr/hal-03216273

AR: Thank you for your suggestion. Unfortunately, none of the authors were able to download this report in English. We are only able to access an abstract in English. If the number of references for the manuscript type “Brief communication” wasn’t limited, we would have added the reference. However, in this case, we would like to keep the report by MeteoSwiss, which is available in German (cited), French (https://www.meteosuisse.admin.ch/content/dam/meteoswiss/fr/service-und-publikationen/publikationen/doc/202102_f.pdf) and Italian (https://www.meteosvizzera.admin.ch/content/dam/meteoswiss/it/Publikationen/doc/202102_i.pdf).