Interactive comment on "Autonomous Ice Sheet Surface Mass Balance Measurements from Cosmic Rays" *by* Ian M. Howat et al.

Anonymous Referee #2

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Autonomous Ice Sheet Surface Mass Balance Measurements from Cosmic Rays
Ian M. Howat, Santiago de la Peña, Darin Desilets, Gary Womack

General Comments

This paper describes the application of a cosmic ray neutron-sensing instruments to measure snow accumulation in m water equivalents on the Greenland ice sheet. The manuscript is reasonably well written, though a bit sloppy. I appreciate the potential of this method for glacier applications, though the results are not very surprising or new

since the method is already successfully used for several years in Alpine terrain. The manuscript should make is much more clear what the added value of this study is.

Specific comments

My main comments regarding this manuscript are the estimated uncertainty, and the sloppy writing style.

The sloppy writing style results in ambiguities. To give some examples:
What is the difference between the 'reference sensor count rate Nr' and the 'reference count rate Ns',
What is plotted in figure 2a? In the caption it is stated: corrected relative count rate, followed by N/N0, but in the text N* is the corrected relative count rate. In the list of corrections asked for below, more of these errors are noted.
Throughout the text when you refer to mass balance the units do not make it clear that you are talking about mass in m water. Since often mass balance observations are measured in m snow or ice, this is confusing.

Another point is the provided final uncertainty in the method. Only using daily scatter in hourly estimates to estimate the uncertainty does not account for uncertainties introduced by the background signal correction and the atmospheric moisture content correction, or the absolute uncertainty compared to the other two methods.

I also found the abstract not easy to comprehend without having read the manuscript.

Since this method is not new, the introduction should be much more clear in what the additional values of this study is. The conclusions are much clearer about that. What I am also missing in the introduction is a comment to the fact that although this adds a method providing mass balance in m water, this still is a point or local measurement. It does not resolve the problem of obtaining a mass balance estimation for the total ice

sheet. For that satellite methods and/or models are still the best option.

Technical corrections

Abstract

P1 L10: Replace 'a reliable remote sensing method' by 'reliable remote sensing methods'.
P1 L12: Replace 'four decades ago' with exact time period. In a couple of years, this is not correct anymore.
P1 L20: Is 'greater' correct English, perhaps 'larger' is better?
P1 L21: Note that 2 years of observations is not enough to make any statement about seasonality.

Introduction

P1 L28: Remove 'of' between 'the' and 'volume'.
P2 L7: I am missing a sentence about the pro's and con's of modelling. For example that it still needs direct observations for evaluation of the results.
P2 L23: 'soil moisture' in snow? Rephrase or explain.
P2 L23: Introduce abbreviation 'swe' and also use it throughout the text! It is not clear when you refer to m water or m snow/ice.
P3 L2: Add 'the' between 'in' and 'center'
P3: Given the work by Kodama and Paquet and Laval, what does this study add? From the Introduction, that is not obvious. Also note that the presented method, although perhaps more than a point measurement as presented by a stake or sonic ranger, is still limited in horizontal extent. In that sense, you need other methods such as remote

sensing and/or modelling. This limitation is not mentioned in the introduction.

Instrument Deployment

P2 L12: (and throughout the manuscript) I prefer a consistent use of units m, kg, m or mm w.e.. Now it varies throughout the manuscript.

Count Rate Correction and Conversion

In general, this part is not well written, parameter abbreviations and descriptions are mixed up, also in the figures.
P3 L22: Remove the first 'background'. Note that you use different terms for this correction: background cosmic ray and solar correction. This is confusing.
P3 L25-27: What is the difference between reference sensor count rate and reference count rate?
P4 L12: Not clear what is plotted in figure 2a, caption and axis do not correspond with description here. $N*/N0$, where does this value come from, and is this plotted? Same for next line.
P4 L13: 'increase more steeply' I understand what you mean, but the line in the figure is less steep, which is confusing with this text. Rephrase.
P4 L15-16: sentence about 'resolution' reaching 1 cm for 1 count, is not clear. Please rephrase.
P4 L17: remove 'that' before 'resolution'
P5 L10: How is this assessed? in absolute sense, of in standard deviations?

Results

P5 L12: provide parameter abbreviation (N?)
P5 L19: the 30-day oscillation is not really visible, especially since the cycle in the annual pressure correction is so obvious.
P5 L19: Value 0.5 given, shouldn't this be 0.05?
P5 L28: The stable periods and declines are hard to distinguish.
P6 L1: Note that the variations are large, figures are mostly plotted with logarithmic scales.
P6 L10: here 'mean daily water equivalent accumulation rate' is used, the caption of figure 5 is slightly different, as is the axis description.Please make them consistent.
P6 L10: The value of 0.078 is not visible in the figure, and which figure do you refer to? 5a?
P6 L21: add unit for the value of 16 May.
P7 L1: is this the difference between the cosmic method and the cores?
P7 L2 and L8: explain what r2 is.

Summary and conclusions

P7 L13: emphasise that the values given by the cosmic method are direct mass values, whereas most other methods need a conversion from height change to mass providing a density.
P7 L16: On P6L1, the value given is 0.007, here a value of 0.0071 is given, be consistent.
P7 L21: Note that 2 years of observations is not enough to make any statement about seasonality.
P8 L13: correct 'wouled' to 'would'.

C5

Figures and tables

Table 1: What is cph stand for? Better use 'hPa' instead of 'mbar'.

All figures: provide (correct) parameter abbreviations in ALL figure captions and axes. Figure 2a: not clear what is plotted here. Description in caption, axis and in text do not correspond. Also mention correct parameter abbreviations in ALL figure captions and axes.