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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Spatial and temporal variability of snowfall over Greenland from CloudSat observations" *by* Ralf Bennartz et al.

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Dear Dr. Jayanarayanan Kuttippurath,

I have reviewed the manuscript "Spatial and temporal variability of snowfall over Greenland from CloudSat observations" by Ralf Bennartz and colleagues, submitted for publication in Atmospheric Chemistry and Physics.

The paper explores various datasets in order to assess the accumulation of snow over Greenland. The authors begin by evaluating the ground clutter of the Cloudsat satellite, comparing it with altimetry measurement, thus interfering with the signal of the snowfall rate. They then correct this radar signal to compare it with a ground radar (MMCR from ICECAPS) to determine a correction for the precipitation process between about

1200 and the ground level. Finally, they propose a set of Z-S relationships applied to CloudSat based on Summit observations to determine a snowfall rate on the surface, compared to snow accumulation observations by stacking method.

The authors conclude their study with an estimate of snow accumulation above Greenland of 34 $\pm$ 7.5 cm/year, with an accumulation above Summit of 23 $\pm$ 4.5 cm/year, consistent with surface observations where ERA-Interim under-estimate this rate.

The topic of the paper is certainly appropriate for Atmospheric Chemistry and Physics, and assesses the CloudSat measurements as an effective tool for studying Greenland precipitation. I have already proposed several questions and suggestions about this paper, the quality of the writing has indeed been greatly improved, but most of my questions remain unresolved.

Sincerely,

Florentin Lemonnier

Science questions

- Page 8, line 20 - When you re-derive the snowfall rate based on the 5^{th} bin of CloudSat, could you explain how do you proceed ? For example, if the IceBridge BedMachine surface topography bin is lower than the CloudSat digital elevation model, are you considering a linear interpolation of the difference of both topographies between the 4^{th} and the 5^{th} bins of CloudSat?
- Page 8, line 24 - It is indicated that differences between the two digital elevation models are caused by melting in ablation zones. In the context of global warming, using such a long dataset as CloudSat without comparing it to a topographic dataset that does not evolve over time could it add uncertainties?
- Figure 3 - As in this figure, could you show a figure of the initial and corrected

snowfall rates? I suppose that the ground-clutter affected measurements, as seen in figure 4, could be observed when the differences in elevation between BedMachine and CloudSat are strong.

- Page 10, line 11 - How did you establish this equation?
- Figure 7 - This correction seems to overestimate the precipitation below 5 dBZ and underestimate the precipitation values between 5 dBz and 20 dBz, as seen in the right panel. In other studies, such as Souverijns et al., 2018, a difference between measurements at 1200 (CloudSat reference level) and 300 (Micro-rain radar first bin) was calculated in order to propose a discrepancy between 1200 m and surface snowfall rates, what could it provide for this study?
- Figure 10 - Again, the correction you are applying on the different Z-S relationships seems to overestimate surface precipitation. A first comparison between CloudSat and MMCR datasets, then would a comparison between MMCR 1200 m.a.g.l. and ground levels be more interesting for evaluating the rate of snowfall at the surface?
- Figure 10 - What are the confidence intervals of these Z-S relationships?
- Section 3.4.2 - In my opinion, this part should be further developed. Indeed the revisit time at Summit is low and the satellite must certainly be missing a large number of events, as seen on figure 12. However, it seems to overestimate other events significantly. Could you first study and show the occurrence of Summit precipitation events observed by ground instruments, stacking field and satellite, thus recomparing the observed ground precipitation rates with the assumed CloudSat rates? As done in the study by Souverijns et al., 2018, could you discuss about commissions and omissions errors of the satellite in order to give a better estimate of the precipitation rate spatial and temporal uncertainties of

CloudSat? Are you taking into account and can you quantify blowing snow processes over stacking field on the accumulation rate, that are impossible to take into account on CloudSat measurements, occurring at low altitude?

- Page 22, line 1 - You are assuming an uncertainty on CloudSat measurement over the GrIS of 7,5 cm/year based on the spread of the Z-S relations, but hat confidence do you place in these relationships?
- Figure 19 - What does this study show about the period from 2006 to 2011, before the failure of CloudSat, where day and night observations can be considered?
- Figure 20 - Are these CloudSat measurements assumed at the surface or observed at 1200 m.a.g.l.? What is the S-Z relation used for the MMCR?

References

Souverijns, N., Gossart, A., Lhermitte, S., Gorodetskaya, I. V., Grazioli, J., Berne, A., Duran-Alarcon, C., Boudevillain, B., Genthon, C., Scarchilli, C., and van Lipzig, N. P. M.: Evaluation of the CloudSat surface snowfall product over Antarctica using ground-based precipitation radars, The Cryosphere Discussions, 2018, 1–21, https://doi.org/10.5194/tc-2018-111, https://www.the-cryosphere-discuss.net/tc-2018-111/, 2018b.