

# ***Interactive comment on “Present-day and future Greenland Ice Sheet precipitation frequency from satellite observations and an Earth System Model” by Jan T. M. Lenaerts et al.***

## **Anonymous Referee #3**

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Review of tc-2020-31

This manuscript examines the current state of precipitation around the Greenland Ice Sheet (GrIS) using precipitation products from CloudSat (CS). It partitions the frequency of the snowfall into regions of the GrIS as well as looks at impacts based on elevation. The manuscript looks at both snow (moderate and light) and rain (light only) and compares to both CESM findings of current day and future projections. In general, CESM overestimates the rainfall frequency, but reproduces the spatial and seasonal variability when compared to CS. Under future warming conditions, the authors find that rainfall will increase at higher elevations of the GrIS, whereas snow only increases

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in the highest elevations (>2500 MASL).

Overall, this is a well-written and organized manuscript. I believe that the material is novel and will add to our understanding of future impacts of precipitation to the GrIS. I have only some minor comments and suggestions of added references in some areas where I think they would help broaden or support the manuscript. These are listed below:

\* The introduction could benefit with a little more background and citations (especially the first three paragraphs). For example, please cite: ...”equivalent to 7.3 meter sea level equivalent.” (P1, L15), ...”driven by a progressively declining SMB.” (P1, L20). Also, could you add any comments on recent data from GRACE or IceSat2/IceBridge in constraining some of these measures of SMB somewhere in the Intro?

\* Could you please add McIlhatten et al. (2019 TCD – in revisions) as well at “and GrIS precipitation rates (Bennartz et al., 2019)” (P2, L31)? McIlhatten et al. also examines the frequency and rates of snowfall over the GrIS (<https://www.the-cryosphere-discuss.net/tc-2019-223/tc-2019-223.pdf>)

\* This comment relates to what you say on P2, L33: “In particular, CloudSat radar reflectivity profiles are contaminated by ground clutter in the bottom kilometer of the atmosphere...” Both Bennartz et al. (2019) and McIlhatten et al. (2019) examine the impact of the ground clutter and the accuracy of the lowest available bin on snow rate information. McIlhatten et al. found that up to 25% of the light snow-producing mixed-phase clouds are likely being missed by CS, when compared to studies at Summit Station (Pettersen et al., 2018 (ACP)). It might be good to have some discussion of this in the data and methods section. I do not think that it fits in the introduction and I do not think it will detract from the overall narrative, but I think some discussion or inclusion of the ground clutter/detection issues in the Data and Methods section would be helpful. It might also be helpful to show the definitions of “light” versus “regular” snow and rain in the methods (I did find it in Kay et al., 2018, but it would be nice to include here as

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well).

\* P4, L9-11 I would add some citations of previous precipitation studies that agree with these findings. For example, “to >30% over Southeast Greenland” is consistent with previous studies, such as: Schuenemann et al., 2009; Hakuba et al., 2012; Berdahl et al., 2018. And “The interior experiences snowfall most frequently in the summer (JJA, >20%),” is in line with ground-based studies from Summit Station, so I suggest noting that and adding the citations: Castellani et al., 2015 (<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015JD023072>) and Pettersen et al., 2018 (<https://www.atmos-chem-phys.net/18/4715/2018/acp-18-4715-2018.pdf>). Throughout this paragraph, it would be helpful to note previous work that is consistent with these findings (similar with the rain frequencies).

\* Figure 3 caption implies there should be dashed lines, but they are not shown. It does say “not shown” in the text (P5, L7). I think it would be nice to show these. Also, this is in agreement with what McIlhattan et al. found (see figure 7).

\* P6, L1: You say “In contrast, interior GrIS summer snowfall frequency is slightly lower in CESM than in CloudSat.” Both Pettersen et al. (2018) and McIlhattan et al. found that mixed-phase clouds were the dominate cloud type producing snowfall in the summer (as opposed to deep, frontal clouds). CS misses many of these lightly precipitating mixed-phase clouds (especially over the interior where CS was compared to Summit Station instrumentation). Is it worth noting this point? Either here or in the discussion? It could be that CS is missing some of this summertime precipitation that is actually being modeling correctly?

\* Figure 6: just a comment that not only does the heavier snow seem to have less of a seasonal cycle, it seems to be completely missing the uptick in SON that is due to the firing up of the NA storm track. Just a comment – but does CESM not accurately capture the NA storm tracks impinging the GrIS?

\* P8, L3-4: “A part of these discrepancies between CESM and CloudSat may be as-

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cribed to CESM (at its horizontal resolution of 1 degree) not resolving the steep topography and related surface climate and precipitation gradients of the marginal GrIS” – also, Bennartz et al., (2019) showed that CS additionally has a very difficult time resolving the precipitation accurately in the steep topographic regions (as well as other studies focused on CS and GPM orographic impacts). Could it also be that both CESM and CS have difficulties here? Might be worth noting – I am not sure I would say it is all CESM.

\* P9, L9 -10: “The increase in GrIS interior snow frequency is consistent throughout all seasons, and most prominent in winter (DJF)” – any speculation as to why? Is it temperature driven, moisture? (either here or in the discussion).

\* Figure A1 is not really in an appendix. Is it worth just adding it as a regular figure? Or adding a proper Appendix with some verbiage?

\* Final comment – Much of the above comments/citations could be added either where I noted or in the discussion. I think adding some of the above gives the paper more context.

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