**Reviewer #1**

Lenaerts et al. use precipitation frequency observations from CloudSat to evaluate the accuracy of the Community Earth System Model (CESM) across the Greenland Ice Sheet. They find that CESM is able to reproduce present-day spatial patterns and seasonality of precipitation frequency fairly well. This lends confidence to their assessment of future precipitation frequency changes by 2080-2095. Overall, the paper is well-organized and easy to follow. The methods are clearly articulated and the results are thoroughly described. The discussion recognizes the limitations of CloudSat and the biases in CESM and presents a very insightful explanation about how we can use Earth System Models to make precipitation forecasts for the Greenland Ice Sheet. I have a few suggestions that would improve the manuscript which I detail below. The main ones are to tidy up the first three paragraphs of the introduction and describe a bit more about how this study will actually aid future satellite planning campaigns. If the authors can address my relatively minor comments, I would be happy to endorse publication in The Cryosphere.

Title: I would urge the authors to consider replacing “satellite observations” with “CloudSat” and “Earth System Model” with the “Community Earth System Model” in the title. Being more specific would probably make the paper more searchable.

We changed the title accordingly.

P1 L16: “Clearly” is vague, how do we know that mass loss has accelerated? Models? GRACE?

We changed this sentence to ‘observations indicate that GrIS mass loss has accelerated’

P1 L19-20: Consider adding a reference that supports this statement.

We added a new reference to support this statement: the new IMBIE assessment of Greenland Ice Sheet mass balance (Shepherd et al., 2020)

Shepherd, A., Ivins, E., Rignot, E., Smith, B., van den Broeke, M., Velicogna, I., et al. (2020). Mass balance of the Greenland Ice Sheet from 1992 to 2018. *Nature*, *579*(7798), 233–239.

P2 L3-4L: According to observations, precipitation decreased in western Greenland between 1996 and 2016 (Lewis et al. 2019; https://doi.org/10.5194/tc-13-2797-2019). Consider clarifying that this statement refers only to models.

Thanks, we added 'climate modeling indicates that' and added the Lewis et al., 2019 to the statement 'with only an increase over parts of the interior'.

P2 L7-9: There are two nice papers that were recently published in Science Ad- vances that investigated this feedback. Consider referencing Noël et al. (2019; https://advances.sciencemag.org/content/5/9/eaaw0123) and Ryan et al. (2019; https://advances.sciencemag.org/content/5/3/eaav3738).

Both references are added to the revised manuscript.

P3 L5-6: I was interested to learn about the "implications for future radar missions" but was disappointed that this was absent from the discussion and conclusions. Either remove this statement or discuss the implications for future radar missions in the manuscript. I would urge the latter to round off a very nice paper.

We agree with the reviewer (as well as the other reviewers) that a discussion of this is a welcome addition to our paper and increases its significance. Therefore we added this paragraph to the discussion:

"In addition to understanding the impact of changing precipitation frequency on the GrIS surface, our methodology can be used to assess what a future CloudSat-style mission would observe in terms of changes in GrIS precipitation. Cloud radars are, and will remain, essential to continually monitor polar precipitation, for a variety of reasons. Firstly, they measure at the right frequency: cloud radars (94 GHz such as CloudSat) provide the only spaceborne radar observations of high-latitude precipitation that have ever been made. Future missions currently will have this frequency: ESA's EarthCARE (https://earth.esa.int/web/guest/missions/esa-future-missions/earthcare ; to be launched 2021) and NASA's ACCP mission (https://science.nasa.gov/earth-science/decadal-accp). In contrast, lower frequency precipitation radars (e.g., TRMM, GPM) cannot detect light precipitation, which commonly occurs at high latitudes, including Greenland (as shown in this study). Secondly, CloudSat regularly samples the high latitude regions, whereas precipitation radars typically do not sample high latitude regions. Future cloud radar missions should continue to consider (near-)polar orbits to include high latitudes. Thirdly, co-locating spaceborne cloud radar with spaceborne lidar can help with assessment of light precipitation and precipitation phase. While our study only focused on CloudSat, future work should complement CloudSat radar retrievals with collocated CALIPSO lidar information to study high latitude precipitation. Both the future EarthCARE and ACCP missions plan to include complimentary radar and lidar retrievals.

Unfortunately, CloudSat only provides a ‘curtain view’ of cloud and precipitation vertical structures at high latitudes, and still provides relatively limited temporal coverage. Creative ways to combine CloudSat-like observations with meteorology can help isolate process-based relationships (e.g., Morrison et al. 2018; Gallagher et al. 2020). However, long-term (decadal or longer) data records are likely needed to isolate change from internal variability. For planning future Earth-observing missions, satellite simulators can give a preliminary peek into potential findings, and provide initial assessments of how long a data record is needed to detect Greenland precipitation changes due to climate change. We suggest that future work leverages these tools, which has already been done for non-polar regions (e.g., Takahashi et al. 2019).”

P3 L24: “heavy precipitation” do the authors mean “heavy rainfall”?

We refer both to snow and rain here, so precipitation seems to be valid to use.

P8 L3-13: Might some of these uncertainties be explained by surface air temperatures in CESM being too warm/cold? If so, please discuss.

We would argue that, although surface air temperatures partly determine the precipitation phase (and frequency as well), many factors control precipitation formation (e.g. cloud microphysics, thermodynamics of full atmospheric column, advection, etc.). We think that is clearly beyond the scope of this study to perform a detailed evaluation of CESM1 precipitation formation mechanisms

P9 L2-4: The authors miss an opportunity here to describe the future climate of Greenland according to an Earth System Model and how it differs from the present-day cli- mate. What is the difference in mean average air temps? Is the seasonality of air temps weaker?

The goal of this study is not to provide a general overview of the future climate on the Greenland ice sheet, but to focus on precipitation phase and frequency chases in particular. Other studies have focused on using various versions of CESM to characterize future changes in Greenland climate, e.g. Vizcaino et al., 2014; Muntjewerf et al., 2020. These references are added to the discussion: “Also, this study focuses on future changes in precipitation only, and does not give a more general overview of future climate change on the GrIS that is provided by other studies using different versions of CESM (e.g. Vizcaino et al., 2013; Muntjewerf et al., 2020)."

Vizcaíno, M., Lipscomb, W. H., Sacks, W. J., & van den Broeke, M. (2013). Greenland Surface Mass Balance as Simulated by the Community Earth System Model. Part II: Twenty-First-Century Changes. Journal of Climate, 27(1), 215–226. https://doi.org/10.1175/JCLI-D-12-00588.1

Muntjewerf, L., Petrini, M., Vizcaino, M., Ernani da Silva, C., Sellevold, R., Scherrenberg, M. D. W., et al. (2020). Greenland Ice Sheet Contribution to 21st Century Sea Level Rise as Simulated by the Coupled CESM2.1-CISM2.1. Geophysical Research Letters, 47(9), e2019GL086836. https://doi.org/10.1029/2019GL086836

Figure 7b: Why would there be differences in the grid cell area between CloudSat and CESM? Please clarify.

We acknowledge that 'grid cell area' is confusing; this is simply the total area in each bin. We have changed this to 'Area' instead and divided the number by 10^5 to improve readability of the labels.