

The Cryosphere Discuss., referee comment RC1
<https://doi.org/10.5194/tc-2021-263-RC1>, 2021
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Comment on tc-2021-263

Anonymous Referee #1

Referee comment on "Clouds drive differences in future surface melt over the Antarctic ice shelves" by Christoph Kittel et al., The Cryosphere Discuss.,
<https://doi.org/10.5194/tc-2021-263-RC1>, 2021

Review of Kittel et al.

This manuscript is a well written paper that presents the potential uncertainties we might expect in future surface melt predictions due to the role of clouds. The manuscript is well constructed and uses state-of-the-art regional climate model data but simply passes many of the complexities related to the surface melt – albedo feedback. Before this study can be published the authors should consider a much more careful analysis of the contemporary surface melt production, including a robust evaluation of clouds and their phase-differences. In addition, other influencers of the surface albedo feedbacks should at least be mentioned, such as the role of precipitation (snow + rain!) and the role of cloudy and clear-sky conditions. Below I will divide my comments into major and minor comments and hope to explain my concerns.

Major comments

1. Surface melt and cloud evaluation

The major thing missing in this manuscript is a careful evaluation. Yes, the authors cite several of the studies evaluating MAR energy fluxes, SMB and surface melt rates. However, (future) surface melting is extremely sensitive, especially the role of clouds and their phases. See for instance King et al., 2015 and the study of one of the authors Gilbert et al., 2020. I would like to see more convincing evidence that contemporary melting is accurately modelled and for the right reasons (you yourself note the effects of compensating errors) and that the surface albedo feedback is (reasonably) correct. How does MAR represent surface melting in cloudy conditions and in clear-sky conditions? There are ample ways to improve and extend the surface melt evaluation with this paper. An example is Jakobs et al., 2020, which provides a state-of-the-art evaluation dataset

publicly accessible against which the contemporary melt climate modelled by MAR can be tested.

In addition, before any weight can be given to the modelled cloud fractions, contemporary cloud fractions should be evaluated in more detail. Examples to do this are the Van Tricht et al., 2016 and Lenaerts et al. 2017 papers (I'm not aware if updates of these products are available yet). They provide extensive Antarctica-wide products of liquid and solid water clouds, against which cloud fractions of MAR can be tested.

2. The role of snowfall and rain

This study solely looks at the radiative fluxes and their role in influencing surface melt production. However, especially in a future climate, precipitation rates are also going to increase, including a change in the fractions of rain and snow. Where obviously rain should be added to the surface melt rates (is it?) rain and snow also affect the melt-albedo feedback in several ways. This effect should be discussed. As of now, snow- or rainfall is not even mentioned once in the manuscript, while its relation to clouds is rather obvious. Additionally, a discussion can be added how future precipitation itself is influenced by cloud fraction, as it is likely just as important for ice shelf stability in a future climate as surface melting is.

3. Regional climate

Throughout the manuscript ice sheet wide averages are used, even though about 30% to 50% of all (contemporary) surface melt occurs in the Antarctic Peninsula. Not only will the numbers presented therefore not be completely representative of all Antarctic ice shelves and the Antarctica Peninsula climate will dominate your results, you are also losing a lot of the local climate signals by averaging this way.

It is known (King et al., 2015 and other studies) that the surface energy budget (and hence melting) is heavily influenced by the partitioning of ice/water cloud particles, and that this process is very uncertain (like is concluded by yourselves) and very local. Some attention should therefore be spent on how these processes are governed elsewhere in Antarctica; e.g. do the same sensitivities exist over other ice shelves than Larsen C ice shelf? Some regional case studies should be performed to strengthen the conclusions in this study.

4. Are the melt differences really due to clouds?

If I am not mistaken, the only forcing parameters from the ESMs that directly influence

cloud phase and fractions are temperature and specific humidity. Hence, the results of this study mainly highlight the different equilibrium states of MAR given a set of forcing conditions, as you state in Section 3.2.1. Then, it is not completely clear to what extent the results are related to the actual cloud physics, or just to a different climate state that corresponds with a different cloud setup, including influences of other internal feedbacks you are not discussing. I would like to see some more discussion about this and the fact that the results you present are not due to differences in model physics, but due to differences in forcing conditions. What cloud differences do we see in the forcing ESMs themselves? Are they similar or does MAR really change the cloud behavior? In other studies such as King et al., 2015 or specific ESM intercomparison studies, differences in clouds are really due to differences in model physics which strengthen the case that the cloud representation in climate models should be improved, but that is not the case in this study. Your concluding remark: "...our study stresses the need to improve cloud representation in climate models to better constrain SLR projections" therefore does not really relate to the results of this study.

Minor comments

P1110-12: What do you mean by "increasing melt differences"? Do liquid containing clouds increase the melt differences, or do you mean something else? Please rephrase.

P2117: If you emphasize surface albedo, you should also note the effects of snowfall and fresh snow albedo due to differences in cloud(cover)

P2136: "Bright surfaces". Why does this matter? You do not come back to this

P2136-44: This paragraph is not logically arranged. You note the lack of observations but you do not repeat this and why do high ECSs matter? Try to rephrase and shorten this paragraph.

P2143: The term RCM should be introduced here, after you did introduce the ESMs. And how is an ESM not polar oriented, and a high-resolution model is polar oriented?

P2L61-62: "correctly represents present Antarctic surface melt" -> "present-day" and this should be much shown in much more detail. Compensating errors might result in a correct modelling of surface melt production, but a more comprehensive study should be done. For instance: if the compensating errors are due to compensating clear-sky and cloudy conditions, your results will be hard to believe. Try to show that the contemporary contribution of cloud radiative feedbacks to the surface melt is accurately modelled.

P3L63: "compensating errors" is too vague. Just leave this sentence as "This suggest a correct representation of the SEB, but...."

P3L64-66: "the projected spread in melt" comes out of the blue; can you introduce this in more detail as it is the focus of this manuscript?

P5L126: You average over the ESMs as well? This is not completely clear.

P5L132: Why are you using cumulative numbers? Either convert them into SLR equivalents, or just use the climatological averages in mmWE or Gt...These very large numbers are hard to interpret

P5L138: Same as above but now with cumulative fluxes. How to interpret a cumulative flux of 443.7 W?

P7L153: Some latex errors here?

P7L156-159: Sensible heat can be a very local effect and might be smoothed out by your choice of presenting Antarctica wide averages. Your results might be dominated by the Antarctic Peninsula, which has the largest melt rates by far. It would be interesting to add a bit more regional studies to this study and grasp whether the LWN/SWN – melt correlation is consistent and homogenous across the continent.

P8L185-190: Why so many supplementary Figures referenced? If you need them in the main manuscript, use them! TC has no figure limit, and they can easily be added as an additional column in Fig.2 as well. (this argument holds for all other references of supplementary figures in the rest of the paper).

P10L217: Sentence is unclear. I do not see the value 0.7 reached and surely not by 2040-2060.

P12L260: What is the effect of rain? Should you add this to the melt flux? As this is very important for surface albedo. (and more..)

P12L264: Again, please consider the effects of precip (snow and rain) on the surface albedo

P12L268: Isn't this strong increase in CNRM-CR6 (not also) explained by the larger amounts of liquid precipitation?

P13L274: Again, I think the influence of precipitation changes should not be passed

Figures:

Figure 1: What is the colorbar for 1b, and what is the orange coloring we see?

Figure 2: What is happening with CC in CNRM from 2060 onwards?

Figure 4-6: Isn't there a way to combine these plots (and make room for some of the supplementary figures to be included in the main?)

References

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