Review of “A Lagrangian Analysis of the Dynamical and Thermodynamic Drivers of Greenland Melt Events during 1979-2017”

In this study, Hermann et al. present a lagrangian analysis of one specific melt event in summer 2012 and 77 long-lasting melt events between 1979-2017. The authors use a threshold value for the surface temperature of -1C to identify melt from the ERA Interim dataset. The authors focus on more extreme, widespread melt events with more than 5% of Greenland melting simultaneously, melt occurring above 2000m and only focus on melt events lasting for more than 24 hours. Additionally, the authors also use ERA Interim data to try and establish the underlying drivers of melt events (surface radiative fluxes, liquid water content and others). Furthermore, the authors establish a novel way to identify the main areas of synoptic-scale airmass advection prior and during these 77 more pronounced melt events.

Overall, this study is very well written and consists of a set of nicely presented figures. The approach the authors use is scientifically novel and has the potential to shed some light on the question of how circulation and advection patterns influence Greenland melt.

Scientific assessment

While the general presentation of the study is to be applauded, there are some distinct methodological limitations that render this study likely to be only valid for a subset of the Greenland Ice Sheet due to the inability to resolve the ablation zone with the ERA-Interim data (i.e. the accumulation zone), and only for a specific type of widespread, long-lasting (24h+) melt events, that also affect the bright interior of the Greenland Ice Sheet, where melt dynamics are significantly different to the ablation zone.
However, as it currently stands the authors draw conclusions on the contribution of clouds, humidity and airmass advection to the general Greenland Ice Sheet melt, which simply cannot be resolved spatially (~100 km resolution). Due to the temporal and elevation focus on widespread melt events, which in themselves can only be driven by large-scale anomalous advection of warm and humid airmasses, it seems that the generalisation of the results is likely limited. Overall, more than 80% of all ice melt occurs in the ablation zone - where weather station data shows absorbed shortwave radiation to be the main driver of melt - which is unfortunately not resolved by ERA-Interim data in this study.

Because the data used doesn’t resolve the darker ablation zone, and the initial selection of melt events likely greatly skews the analysis towards longwave and humidity driven melt events at high elevations, the presented results in their current form cannot be presented as being generally valid to all Greenland melt and likely needs a more nuanced presentation throughout the manuscript.

However, I hope that my comments will encourage the authors to slightly rethink some conclusions of their manuscript, after which this paper will be a welcomed contribution to the growing set of novel Greenland Ice Sheet climate literature.

Specific comments

Title: Maybe include "of large-scale" or "extreme" melt events, because for the reader it seems that the authors focus primarily on a very specific subset of melt events, that might not represent the general physical mode of "normal" melt.

Introduction: The introduction was very enjoyable to read and is a very concise account of the current state of the relevant Greenland literature.

Around **L90 –** the main questions the authors want to answer. **Q1)** "How often did melt events occur over the GrIS during 1979-2017?" Maybe mention that the authors focus on widespread, long-lasting melt events that affect the bright ablation zone.
Q3) Also potentially highlight that the radiative effects and air mass modifications are valid for your chosen subset of melt events, not the "normal" GrIS melt. **Q4)** "Does the answer to Q2 and Q3 differ for subregions of the GrIS?" → For the reader the most interesting question would likely be does it differ for the accumulation zone melt events vs. the ablation zone melt events where more than 80% of all melt occurs and where the physical drivers are significantly different due to the difference in albedo.

L94 ff – Era Interim data: At 1° resolution the ERA Interim data does give the authors one pixel in the SW of the GrIS where the ablation zone is at its widest and even less where the ablation zone lies in steeper terrain. Both is not sufficient to resolve the ablation zone. For the reader it seems that the study design is robust to answer Q2 mentioned in the introduction, but Q1, Q3 and Q4 can only be answered for the accumulation zone.

L111 For the reader it likely needs to be made clearer throughout the manuscript that the authors are dealing with a specific subset of widespread melt events, and not the ablation zone melt dynamics that contribute most to GrIS melt.

L135 Is there a previous study that looks at the capabilities of ERA-Interim to accurately model the GrIS boundary layer, given that all the parcels of the authors are starting in the lowermost 500m of the atmosphere?

L195 How did the authors identify the "dry intrusion" near Newfoundland? Isentropic potential vorticity based analysis?

L270 ff Discussion about previously warm and humid airmasses losing their warm anomaly but staying humid. Might it potentially not be better to look at a variable that combines temperature and humidity, such as equivalent potential temperature, to define an airmass? Is there a specific reason why the authors chose not to?

L284 "cloud formation" Until this point the authors did not look at clouds specifically, so some of the changes in radiative fluxes could be due to phase change in existing clouds alone and not just due to extra cloud formation.

L289 How robust is the phase partitioning in the atmospheric column, i.e. is the total column liquid water in ERA-I realiable in high-latitudes? Maybe there is a study to cite that looks at this specifically.

L295 Interestingly, it seems that in the NW of the GrIS there is even a negative anomaly of liquid water content in lower elevation areas, and only when the airmass ascents further it suddenly develops a positive liquid water content anomaly. Any ideas of why that is, given that the airmass in itself likely has a higher specific humidity content than in the climatology overall?

L295-308 Maybe the authors could mention that the discussion here is still focusing at one specific melt event? Sometimes this wasn't clear for the reader.

L319 "In this section we generalize the results from the EV69 case study by considering all 77 Greenland melt events." I think this statement is somewhat misleading. The authors are not generalizing to "all" melt events, but still only to a subset of widespread and longwave driven melt events that reach up to high elevations and last longer than 24h. For the reader this nuance is lacking through most parts of the following and preceding discussion of results and should be added throughout, also that ERA I does not resolve the ablation zone.

L374 "… but now for **all Greenland melt events** in JJA 1979-2017" See previous comment on why this might be an overstatement.

L426 and following section "Linkage to clouds and radiative effects"

The authors likely need to take into account the limitations of their approach here. The used data simply doesn't allow to answer the question of what is driving most of the GrIS melt, given that a great majority of melt occurs in the ablation zone that isn't resolved here. Additionally, the chosen subset of melt events skews the conclusion drawn for the contribution of radiation and clouds to quite obviously longwave driven melt events in the bright accumulation zone of the Greenland Ice Sheet. For the reader this section needs quite a bit more of a nuanced assessment, especially from **L448** onwards, where the authors conclude that the longwave radiative effect of clouds and humidity is the main contributor to melt and enhanced furthers by anticyclonic circulation.

L523 ff "longwave radiation is a key element in triggering surface melt in Greenland and the remaining Arctic". The results here are only representative for the accumulation zone melt dynamics and not Greenland in general. Unfortunately, this statement cannot be concluded from the presented analysis.

L528 ad "ii) causing a positive cloud radiative effect" **–** Yes, but this can only be answered here for the interior of the GrIS where the surface albedo is high and therefore the cloud radiative dynamics are significantly different to the ablation zone (additional to a skewed subset of melt events). Just today a paper has been published that shows that the CRE is negative over the GrIS ablation zone during summer, and positive over the accumulation zone.
(https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2020GL087315).