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Interactive comment on "Energetics of Surface Melt in West Antarctica" *by* Madison L. Ghiz et al.

Anonymous Referee #1

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Summary

The manuscript uses multiple data sources (satellite, AWS, reanalysis) to explore the contributing meteorological factors influencing the SEB and surface melting over West Antarctica. Specifically, the authors examine the influence of optically thick cloud that induces a thermal blanketing effect, optically thin clouds that enhance all-wave radiation, and foehn winds. They explore these mechanisms by evaluating several case studies from various locations in West Antarctica.

Adherence to evaluation criteria

This paper specifically examines the effects of processes that have previously been considered in isolation or in a less direct manner, and quantifies their impact on melting by unravelling their effect on the surface energy balance (SEB). This represents new insight and advances our understanding of cloud processes and foehn events on the

SEB of West Antarctica, and so demonstrates the originality required for publication in The Cryosphere and fits well within the aims and scope of the journal.

Overall, I am convinced of the scientific rigour of the methodology and believe that the manuscript contains enough detail to make the methods reproducible. I have some minor comments and clarifications on certain aspects of the methods, which are given below. The specific contributions of this work in relation to the existing literature could be outlined more explicitly, but generally there is adequate consideration of related work. The limitations of the method are discussed and addressed appropriately.

The results and conclusions are presented clearly, although the text can be overly descriptive and somewhat repetitive in places. I have provided some suggestions for re-structuring some of the case study sections to improve readability. Overall the language is satisfactory, but there are still some outstanding typos and errors that could be rectified with a thorough proof-read. I have highlighted some below in my comments. The figures used are appropriate but are again repetitive. I have offered some suggestions in my comments that may enhance the reader's understanding of the results.

The authors reach substantial conclusions regarding the importance of the three mechanisms outlined for determining melt. These findings are likely applicable to other parts of Antarctica, which gives them broader significance. The results fit within the current literature regarding Antarctic SEB and the drivers of melt, and represent a development in our scientific understanding of the effect of cloud properties and atmospheric dynamics on melting.

General points

- The manuscript is very descriptive, at times overly so. It may help the reader if you more explicitly draw the links between the general synoptic conditions that are described at the start of each case study and their impact on the mechanisms involved and the SEB/melt.

- Each of the case studies is comprehensively evaluated and a great deal of analysis has evidently been done. However, it does get a little repetitive reading each of the case studies in turn because they all follow the same structure. My suggestion would be to combine the discussion of e.g. Siple + PIG/Thwaites (2nd and 3rd cases), and possibly the Ross Ice Shelf (6th case) into a 'December 2011' case, which might help the reader and facilitate better discussion of the influence of synoptic meteorology on melting at these two/three locations. You can then discuss the ways the same event affects the SEB similarly/differently at the different sites.

- The similarity of the figures is also a little repetitive. Whilst I understand that this is difficult to avoid because of the nature of your analysis, I wonder if there is a way of combining some elements of the figures to communicate the differences between case studies/mechanisms more concisely? For example, could you show a scatter plot of IWP/LWP vs melt or Rnet for the optically thin/thick cloud cases to see how the optical depth influences these? Or contrast the time series of melt/emissivity for different case studies in one figure with multiple sub-plots? Some spatial representation of these case studies, e.g. maps of ERA-5 modelled ME, synoptic meteorology, emissivity or specific fluxes might also help the reader understand these cases better.

- It would be helpful for the reader to more clearly indicate which mechanism you believe is responsible for driving melt at the start of each case study section, possibly even in the subtitle heading.

- I would like to see more discussion of the impact of cloud phase on melting. Ice and liquid have quite different radiative impacts, so this might affect your results.

- More concrete linkages should be drawn between the melt mechanisms and large-scale drivers, such as those identified by Scott et al. (2019).

- If you only refer to something once or twice, you probably don't need to define an acronym for it (e.g. ARM, ARs, GIS, AMRC, DMSP). This helps the reader because they don't have to refer back to remind themselves what the letters stand for.

- Do you see the effect of the Amundsen-Sea Low (ASL) in your results? This has been shown to be linked with the SAM (and ENSO) and can influence the advection of maritime air onto the continent (Hosking et al., 2013 – doi:/10.1002/joc.3558 ; Clem et al., 2017 doi: 10.1175/JCLI-D-16-0891.1)

- How do your results compare with high-resolution regional modelling? Are there implications for e.g. surface mass balance? E.g. Lenaerts et al. 2017 doi: 10.1017/aog.2017.42; Deb et al., 2018 doi; 10.1029/2018GL077092)

Specific points

[L35-37] This would be a good place to reference Lhermitte et al. (2020) on structural destabilisation of West Antarctic ice shelves. doi: /10.1073%2Fpnas.1912890117

[Para starting L80] quite verbose, could be revised to be clearer

[L83-85] Does the fact that the satellite retrievals are instantaneous affect melt detection?

[L105] define GIS on first usage

[L106-107] Suggest including a citation to support this point (frequency of cloud LWP 10-40 g m-2 in the Antarctic, plus radiative effect of this cloud)

[L111-116] Citation for definition of foehn – e.g. Elvidge & Renfrew (2016) for various mechanisms doi:/10.1175/BAMS-D-14-00194.1

[Section 2] How are foehn detected in the AWS data? Further detail is required here.

[L186-194] Discrepancies of 50-100 W m-2 are quite considerable, and certainly could mean the difference between melt and no melt, especially in non-summer seasons. All reanalyses struggle with cloud properties, so you would expect some level of disagreement in terms of radiative fluxes, but I wonder if this could be improved upon. Did you look at any other reanalysis products to find out whether any others perform better?

[L206] comma should be after ‘event’ not ‘melt’

[Fig 2] Is there missing data in panels d and e between December 10-11?

[L263] missing full stop after parenthesis

[L276] misplaced comma – add after ‘daily statistics’

[L 280-281] Explanation of Fig 5b unclear. Suggest that you explain which 5 cells were selected and/or how they were chosen, and rephrasing to more clearly state that these are expressed as percentiles of the max Tb observed with satellite retrievals.

[L292] Some comment on how you might expect the high IWP values used in the ERA5 radiative transfer scheme to influence the radiative fluxes would be informative here. e.g. competing SW/LW effects

[293-295] What is the implication of the greater vertical extent of cloud ice vs liquid regions? How might this influence the surface energy balance? I am wondering about e.g. temperature and altitude effects, as well as how the ice/liquid water paths influence LW/SW scattering and emission of the clouds. Cloud vertical profile is shown to be important in determining radiative flues and melt in e.g. Gilbert et al. (2020) doi:10.1002/qj.3753 on the peninsula in summer.

[L322] missing ‘the’ before ‘lowest sun’ ?

[L323-325] Quantifying these statements would be helpful. What, specifically does ‘unexceptional’ mean? Perhaps give an average. Similarly for ‘moderate to high LWP’.

[para beginning L318] Presumably the source of the SH flux is warm air advection associated with the warm air intrusion during Dec 2011? Possibly worth re-stating this here.

[327-330] Further explanation of the mechanisms causing delayed-onset melt and then sustained melt would be informative.

[L331-332 (Fig 8 caption)] See comment above at line 280-281.

[L344] Not sure ‘low overcast’ is a noun. Please revise (e.g. low cloud/ overcast conditions/ similar)

[L358-361] Can you speculate about sources of homogeneity in the emissivities? E.g. snow properties, surface albedo, melt ponding, topography etc.?

[L381-383 (Fig 11 caption)] See comment above at line 280-281.

[Section 3.3] – I would consider combining this section with 3.2 (and possibly 3.6) in order to better discuss the influence of synoptic conditions on the cloud properties, emissivity and SEB at these locations. As it is, the manuscript is quite repetitive as each case study follows the same format with very similar figures, so this may help the reader draw parallels and distinctions between the same event manifested at different locations.

[L435-436 (Fig 14 caption)] See comment above at line 280-281.

[para beginning 445] – this sounds like the signature of the ASL in the Ross Sea. Could be worth tying this in, to make more connection between large-scale synoptic conditions and local effects.

[L499-501] This signature (positive SH, negative LH) is frequently indicative of foehn conditions. Adding a statement + citation to this effect would strengthen your argument (e.g. Datta et al., 2019; Elvidge et al., 2020, 10.1029/2020JD032463; Kuipers Munneke et al., 2012, doi: 10.5194/tc-6-353-2012; 2018, doi:10.1029/2018GL077899).

[L514-516] Might the optically thin clouds suggested by your results be indicative of the ‘cloud clearance’ effect of foehn? i.e. clouds that might have been optically thicker in the absence of foehn (such as those you have shown at PIG/Thwaites/Siple Dome) due to the presence of warm, moist air from the Southern Ocean are thinned by the warming/drying effect of foehn?

[para beginning L566] Might ground-based remote sensing from the AWARE project be useful for examining cloud microphysics? Could this be a way of improving the detection of these sorts of cloud-driven melt events?

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