Surface melt on the Shackleton Ice Shelf, East Antarctica (2003-2021)

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General comments:

This manuscript investigates the spatiotemporal variability in summer surface melt on the Shackleton Ice Shelf over the past two decades (2002/3 – 2020/21). The authors use a machine learning approach (a self-organising map) and passive microwave AMSRE data to identify nine representative patterns of surface melt on the ice shelf over this period. Finally, they use these patterns to demonstrate the importance of surface air temperatures, katabatic winds and surface albedo in controlling summer melt.

Surface melt is an important component of ice-sheet surface mass balance, leading to surface meltwater accumulating in depressions on ice-shelf surfaces. This has been linked to the process of meltwater-driven hydrofracture, which can trigger rapid ice-shelf collapse. Quantifying surface melt extent and duration and understanding the controls on this variability is therefore important for evaluating future melt projections. Melt metrics from satellite-derived observations have typically been used to quantify surface melt. However, few studies have quantified the extent and occurrence of surface melt and its interannual variability on East Antarctic ice shelves.

This manuscript builds upon previous work by providing the first assessment of interannual variability in summer surface melt on the Shackleton Ice Shelf, potentially one of the most vulnerable ice shelves in East Antarctica to future meltwater-driven collapse. The novel approach of a self-organising map is used to evaluate this, the first time this has been done in Antarctica. It also provides useful insight into the local controls on the occurrence of surface melt, building upon recent work linking localised katabatic wind controls on seasonal supraglacial lake evolution on this ice shelf.

Therefore, it is my view that the findings are of broad interest to the cryospheric community and represent a promising step forward for studying the spatial and temporal variability of surface melt and its controls, especially in the context of ice-shelf surface hydrology and dynamics. I look forward to seeing further development of this method and its applications on other Antarctic ice shelves.

In general, this is a well-written manuscript and most of my comments are relatively minor. Once the authors address these, I can therefore recommend that this manuscript is suitable for publication in *The Cryosphere*.

Specific comments:

Line 29: I think it is worth highlighting here how intense surface melt can precondition ice shelves for collapse by depleting their firn air content. Think about adding an additional sentence or two here about the specific role played by anomalously intense surface melt preceding the break-up of Larsen B (e.g. van den Broeke, 2005).

Line 34: 'melt events' → specify timescale, i.e. over several days. Similarly on Line 35: 'longer records' → specify multiannual.

Line 36: Specify melt metrics which are typically used (melt onset/freeze-up dates, melt season length, total number of melt days).

Line 61: I suggest citing Miles et al. (2020) here, who recorded acceleration of Denman Glacier since 1972, driven by grounding line retreat, ice tongue thinning and unpinning (see References below).

Line 71: Define SSM/I and SSMIS acronyms.

Line 84: I would perhaps clarify here how you define dry snow recursively?

Line 95: It isn't clear to me what you mean by erroneously missing melt events – do you mean you want to exclude any melting that could be occurring on the sea ice?

Line 119: I would refer to Section S1 in the Supplement here, with the useful description for understanding the SOM output.

Line 165: I would change the order in which the different patterns are discussed, and displayed in figures 2 and 5 – it is slightly confusing to start with patterns 8 and 9 (though I can see why you have done this as they are the most prevalent). Consider re-ordering sequentially.

Line 176: Specify what you define as the melt season (i.e. I assume November to February?).

Line 192 (Figure 3): I think it would be useful to show calendar dates on this figure (i.e. merge Fig. S6 with this one). Would it be possible to add a second x axis to show this? The colours of SOM Patterns 1 and 7 are also very similar, consider changing one.

Line 217: I think Figure S8 is interesting and should be brought into the main manuscript. While Fig. 5 is useful for demonstrating the large interannual variability, particularly in the two 'extreme' end members i.e. Patterns 9 and 1, I think Fig. S8 provides useful context for interpreting the temporal variability in melt patterns across the shelf.

Line 229: Could you add Cumulative Melt Surface into the Table caption to remind the reader, given that the other acronyms are defined here.

Line 261: Add a brief summary of RACMO2.3p3 in Section 2, as it is not currently mentioned in the description of datasets. Is it forced with ERA5? And reference van Dalum et al. (2022).

Line 244 (Figure 6): Consider in Panels (a) and (d) changing scale units from 'Days since 1st Nov' to Date, I think this would make it easier to see spatial variability through the melt season.

Line 342: Could you quantify how much RACMO overestimates melt along the grounding line? It looks like ~25-75 mm w.e yr^{-1} from van Dalum et al. (2022)?

Technical/minor corrections:

Hyphenate ‘sea-level rise’ (e.g. Line 15 – check throughout).

Line 54: I suggest replacing ‘runs for’ with ‘extends for’.

Line 55: Replace ‘lay’ with ‘lie’.

Line 78: 19 GHz (space).

Line 81: Hyphenate ‘horizontally-polarised’.

Section 5.3: Capitalise ‘figure’ throughout.

Line 356: ~~don’t~~ → ‘do not’. Same on Line 328.

References

Van den Broeke (2005) Strong surface melting preceded collapse of Antarctic Peninsula ice shelf. *Atmospheric Science*, 32, 12. Doi:10.1029/2005GL023247.

Miles, B. et al. (2020) Recent acceleration of Denman Glacier (1972–2017), East Antarctica, driven by grounding line retreat and changes in ice tongue configuration. *The Cryosphere*, 15, 663–676. https://doi.org/10.5194/tc-15-663-2021.