

Interactive comment on “Avalanches and micrometeorology driving mass and energy balance of the lowest perennial ice field of the Alps: a case study” by Rebecca Mott et al.

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This paper presents an interesting study on the accumulation and ablation processes of a small mountain ice field, and the factors which may be contributing to its current survival at relatively low elevations. The authors highlight the importance of snow avalanching to the winter mass balance of the ice field, driven by the steep topography surrounding the ice field which captures and funnels snow to its surface. The authors also present a novel use of thermal imagery and boundary layer flow modelling to infer the micrometeorological conditions over the ice field, and to investigate the influence of katabatic air flow on surface ablation.

C1

This work will provide a useful case study to those interested in the surface processes of very small glaciers and ice fields, and in the current and future mass balance response of ice features existing below the climatic snow line. Therefore, I believe this paper should be published in The Cryosphere. Prior to publication, I recommend a number of minor to moderate edits and revisions, which are detailed below.

My primary recommendation is in relation to the boundary layer and katabatic flow findings presented in this paper. While the thermal imagery and flow model provide an interesting overview of the potential boundary layer conditions and turbulent heat flux, I believe the paper currently lacks sufficient detail or findings to support some of the specific claims made regarding the katabatic depth, flow decoupling, and turbulent heat exchange. This could potentially be improved by providing more detail on the methods and further model output which supports these findings. If the authors feel that such detail is not available, then I recommend scaling back on these claims (some specific examples are given in the detailed comments). On a more minor note, although the paper is well written and structured, there are some punctuation issues, and the phrasing at times can hamper the understanding of the point being made, and in some cases, is incorrect. I have outlined some of these, but recommend the authors fully review the text.

Detailed Comments:

P1L26-27: Meaning of this sentence is a little hard to decipher, and it feels like two points have been mixed into one; perhaps rephrase or split into two.

P1L34: 'of the onset' and the comma could be removed.

P2L9: 'them to significant'; remove 'to'.

P2L14: 'the anomalous'; remove 'the'.

P2L23: change 'have' to 'has' or 'effect' to 'effects'.

P2L31: perhaps move 'also' to before 'expected'.

C2

P3L1: 'is assumed to be reasoned by'; rephrase, maybe to 'is assumed to be attributable to'.

P3L18: Perhaps change 'in the centre of' to 'in the interior of', which would appear to agree more with its location on the map in Figure 1.

P3L26: 'in the angle of the rock face, the Ice Chapel'; rephrase.

Section 2.2.1: The authors have provided references to previous studies where mass balance measurements from TLS have been calculated, along with one or two details on their own measurements. I think this section would benefit from a brief but more structured description of the step-by-step process undertaken in this study to obtain the TLS measurements, the calculations to go from TLS measurements to the surface raster to the mass balance estimates, and the associated uncertainties in their values.

P3L36: Insert comma after '(Figure 2)'.

P4L3: Change 'season' to 'seasons'.

P4L6: Add units for '0.002 and 0.05'.

P4L14: Change 'extend' to 'extent'.

P4L15: Change 'allowed to' to 'has allowed for a'.

P4L17: Change 'to retrieve' to 'for the retrieval of'.

P4L17: 'surrounding' to 'surroundings', and comma after Ice Chapel.

P4L23: Change '0,01' to '0.01'.

P4L24: Add bracket before 'LEICA'.

P4L25-26: 'was checked and updated to changes applying the bundle block procedure'. I was uncertain of the meaning of this; consider rephrasing or expanding.

P5L6: At what height above the surface were the measurements taken? Was this

C3

consistent at each location?

P5L7: '12:00 AM' should be 12:00 PM (noon). This is repeated at a number of locations in the text and in Figures 2 and 10.

P6L15: 'An' instead of 'A'.

P6L18: What is the near-surface vertical resolution of the model? Over steep terrain, the wind maximum of a katabatic flow can occur at very low heights, potentially below 2 m, as has been noted in previous studies (e.g. Denby, 1999; Oerlemans and Grisono, 2002). Are the authors satisfied that the vertical resolution and lowest level of the model are sufficient for representing katabatic flow in these conditions? A line or two on this would be useful.

P6L28: 'generates' instead of 'generate', and 'are likely' instead of 'is likely'.

P6L35: units for '1420'.

P7L1-4: Clarification on what is your measure of atmospheric stability is required. I would be wary of describing the difference in two air temperature measurements, approximately 2 km apart, as an indicator of atmospheric stability, particularly localized stability. What form of temperature sensor and radiation screen is used at the Kühroint station? Could radiative heating of the sensor at the 'sun-exposed' site be contributing to the higher temperature? Radiative biases in temperature sensors can exceed 2°C, particularly close to noon.

P7L5: Can you define 'slightly stable' in terms of the model set up?

P7L25: Change to 'in the autumn'.

P7L34: 'Strongest reduction of the surface is...'; perhaps add in 'area' after 'surface' to clarify.

P8L35: Add 'of' after 'downstream', and change 'is' to 'are' after leeward slopes.

C4

P9L8: Change 'made' to 'provided'.

P9L13: Remove 'rather' or quantify.

P9L23: Change 'is revealed' to 'was observed'.

P10L5: Perhaps change '12:00' to '12:00-13:00'.

P10L7: Change 'at' to 'on'.

P10L12: Change to 'resulting in an'.

P10L22: Change to 'using an IR camera'.

P10L33: Figure 9 does not have letter labels.

P10L38: Change to 'surroundings', and add comma after 'In the morning hours'.

P10L39: Add comma after 'After 2 PM'.

P12L21-23: How deep are the katabatic flows? Can you provide detail from the model that indicates the depth of the flow and its level of development?

P12L31: Are you referring to the height of the katabatic wind maximum? What height range does the model give for this? How do you know it is overestimated without comparable observations?

P12L40: Again, what is the depth of the katabatic flow?

P13L16: 'well-developed stable layers'; perhaps rephrase this to well-developed katabatic layers, as the development of a stable layer in many environments would not lead to stronger turbulent heat flux.

P13L19-21: 'Turbulent heat fluxes were shown...'; While there may be theory and evidence from previous studies to support this, I do not believe the necessary observation or model data have been presented in this paper to state if and when decoupling of the near-surface layer has occurred (and associated effects). I suggest providing more

C5

evidence of this, if available, from the model (although this will be difficult if vertical resolution is low), or stepping back from saying this has been shown.

P13L27: Change to 'part of the ice field', and 'ablation rates with downwind distance'.

P13L28-30: How big of a role might localised shading effects play in these ablation patterns?

P13L32-33: Have you considered the effect of increased longwave radiation in areas adjacent to the warmed rock face/slopes?

P14L9: Typo 'change'.

P14L20-22: Phrasing makes the meaning a little unclear; perhaps rephrase to '...the existence of the perennial ice fields is due to the anomalous...'

P14L32: How do you define 'very shallow' and has this really been shown?

Figure 1: Icons for Small Ice Chapel and Meteorological stations are hard to see, and I could not see the black perimeter outlining the Ice Chapel. Consider indicating the direction of view for c-e). Also, e) is not referenced in the figure caption.

Figure 2: In the scales, change the apostrophes to commas e.g. 1,000. This is repeated in Figures 11 and 12. Also, AM should be PM.

Figure 7: I would move the position of 'a)' and 'b)' in the caption to the beginning of each description. What does the blue star represent in b)?

Figure 8: It would be useful if one or more of the contour lines had the elevation indicated on them. Figure 9: Consider adding a)-h) labels.

Figure 12: Add time of day to the caption.

Figure 13: Label a) and b). Why do you think sensible heat flux in the lower, eastern portion of the Ice Chapel appears to be more intense during neutral conditions?

References: Denby, B. (1999). Second-Order Modelling of Turbulence in Katabatic

C6

Flows. *Boundary-Layer Meteorol.* 92, 67–100. doi: 10.1023/A:1001796906927

Oerlemans, J., and Grisogono, B. (2002). Glacier winds and parameterisation of the related surface heat fluxes. *Tellus* 54A, 440–452. doi: 10.1034/j.1600-0870.2002.201398

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