01 Review

General

The authors investigate how snow distribution patterns affect the surface temperature of snow on Antarctic sea ice, a key but under-studied factor in the sea-ice energy balance. The introduction puts the topic of the paper well into context and provides a great overview of the current state-of-the-art. To contribute to this vast topic of polar sea ice, the authors applied UAV and ground measurements to create high-resolution maps of snow topography and surface temperature over uniform landfast sea ice in McMurdo Sound, Antarctica. The measurement site, the ground-based and airborne methods are introduced in detail. Regarding the latter, a novel algorithm was developed to correct thermal drift in UAV thermal imagery, ensuring consistent temperature data. Based on these maps and correlations, the authors investigated the reasons for observed surface temperature variations. As a result, the surface temperature anomalies were mainly linked to visible sediment on the snow, not snow depth, which has been the authors initial hypothesis. They further found that small-scale topography significantly affected local solar irradiance, and assuming uniform irradiance underestimated its variability. Overall, sediment and irradiance were found to have a stronger influence on snow surface temperature than snow depth, highlighting the importance of surface features in energy balance modelling on sea ice.

The manuscript provides an important contribution to the analysis of polar surface temperature variations. It presents interesting and valuable results, which help to identify gaps in common surface temperature retrievals assuming flat surfaces. It highlights the problems and mismatches they struggle with and introduces proper solutions. I highly recommend its publication after the authors have revised the manuscript regarding the comments listed below.

Major comment

Length: The paper is very long, which makes it difficult to keep the readers attention from the beginning to the end. However, I think there is some potential to shorten the paper significantly.

1. In my opinion, there is no reason to separate the results and discussion sections. On the contrary, the separation results in a lot of repetition, which unnecessarily lengthens the paper. By merging the two sections, this could be avoided, and the paper could be significantly shortened, which would also make it more focused. The individual sections already have similar topics, so this should be easy to do.

AC: We thank the reviewer for this valuable suggestion and agree that merging the Results and Discussion sections will help reduce redundancy, improve clarity, and enhance the overall focus of the manuscript. We will follow this suggestion and restructure these sections accordingly in the revised version.

2. There are several graphs that represent more or less the same thing. For example, Fig. 1a,b and Fig. 5 a,b. One figure, either a or b, would be sufficient here. Some figures can be merged. For example Figure 8 and 9. Why not have one column with the Red Band Value (G and B are not really used), one column for the DEM and one for the temperature? Furthermore, there are graphs that in my opinion are not needed at all. For example, Figures 10 and 13. I have also made additional suggestions under Minor and Technical Corrections.

AC: We agree with the reviewer's assessment and are going to revise the figure layout accordingly. Specifically, we are going to adjust Fig. 1, streamline Fig. 5 by merging it with Fig. 4 as a third panel. We are also going to combine Figs. 8 and 9 into a single figure with three columns (Red band, DEM, TIR) to enhance readability. Lastly, we are going to move Figs. 10 and 13 to the appendix, as they provide useful background but are not essential to the main narrative.

3. Some further sections can be skipped as own sections and merged into others. For example, the main message from 2.3.4 fits to the introduction of the camera, Section 4.5 belongs to the summary and conclusion part.

AC: We agree with the reviewer and are going to merge Section 2.3.4 into Section 2.3.5 to improve structure and flow. We are also going to move Section 4.5 into the Summary and Conclusions section, as it aligns better thematically.

Figures: The figures are often not really introduced, but are only mentioned in brackets after certain statements, so that the reader has to find out for himself what is shown. This makes it difficult to read fluently and understand directly. It would be good to describe what is shown in the text with one or two sentences.

AC: We agree with the reviewer and are going to revise the manuscript to more clearly introduce and describe each figure within the main text. This will improve readability and help the reader better understand the content and relevance of each figure.

Minor comments:

1. Order: Figures are partly not numbered in the order they are used in the text.

AC: We acknowledge this oversight and are going to revise the manuscript to ensure that all figures are numbered in the order in which they are referenced in the text.

2. Space signs: Space signs are multiple times missing between numbers and units, between figure abbreviation and figure number and in front of citations that are given in brackets.

AC: We acknowledge this issue and are going to correct all spacing inconsistencies throughout the manuscript, including those between numbers and units, figure abbreviations and figure numbers, as well as spacing before in-text citations.

3. Indices and units: Indices are sometimes written in italic letters and sometimes in non-italic letters. For reasons of consistency, you should write all indices in non-italic letters.

AC: We are going to standardize the formatting of all indices in the manuscript, ensuring they are written in non-italic letters for consistency.

4. P2, L46: What means the original hypothesis was? It should stay the same, although it might have been rejected.

AC: We understand the reviewer's concern regarding the phrasing. We will clarify the language to indicate that the original hypothesis remains as stated but that our results do not support it. This will ensure the hypothesis is clearly presented and its evaluation is transparent.

5. Sect. 2.3.2: You might have to revise this section to make it more clear to the reader what happens here. I had to read it several times and I am still not sure if I got it right. Do you match the in situ snow depth measurements by their GPS position into the RGB images? Or is it some kind of a stereographic method? Please revise it to make this easier understandable. Maybe also a sketch might help to better understand the procedure behind.

AC: We appreciate the reviewer's effort to understand this section. We believe the comment may refer more to Section 2.3.3, where we use the DEM rather than RGB images to relate in situ snow depth measurements. Nonetheless, we recognize the current explanation could be clearer and potentially confusing. We will revise this section to provide a more straightforward description of the methodology, including the spatial matching approach between the DEM and in situ measurements, and consider adding a schematic to aid reader comprehension.

6. Sect. 2.3.4: I don't think that this section is really needed. It should be enough, if you mention the conversion within one sentence, when you introduce the camera.

AC: We are going to merge Section 2.3.4 with Section 2.3.5, as suggested above, and will condense the content to a brief mention of the conversion when introducing the camera.

7. Sect. 2.3.5: This is a very well-thought-out method, which leads to convincing results. I just wonder how you derive the absolute calibration. Is it a predefined function for each pixel from the lab, which is then scaled for each pixel by the NUC? Or do you know the temperature of the shutter (which then acts like a black body) and in parallel is used as a homogeneous target to remove the non-uniformity of the single pixels? Furthermore, later in Line 305 you discuss a vignette effect, which originates from the lens properties. That brings me to the question where the shutter is installed. Is it installed in front of the lens or between the lens and the detector? For the latter you will imprint the structure of the lens-own temperature into the images, when you perform the NUC, which then leads to this vignette effect and might also changes the absolute calibration.

AC: Thank you for the insightful questions. Unfortunately, the camera's internal calibration process is not fully accessible to us, and detailed information on the absolute calibration or shutter placement is not provided by the manufacturer (investigation with DJI was unfortunately unfruitful). The vignette effect is taken care by applying an oval mask as part of the AGISOFT Metashape processing workflow (see Fig. 3).

8. Sect. 3: The initial paragraph is a repetition and can be skipped.

AC: We agree with the reviewer and will remove the initial paragraph from Section 3 to avoid repetition.

9. P24, Fig 12: It would be great to have such a "correlation" plot for "degree of sedimentation" vs. temperature. I guess here you would find a significant high correlation. Of course, I see the point with the difficulties related to the varying camera settings as you write in Line 337 and the shadows you mention in Line 408. But shouldn't be the first issue solved by your NUC calibration? Furthermore, you could use your DEM to extract regiones, which might be affected by shadows. Adapting both, you would be able to select scenes, which are unaffected by shadows and after a normalization you can extract an arbitrary value for the degree of sedimentation, which might range from 0 to 1.

AC: We appreciate the suggestion, and the level of detail that the reviewer has thought about this; however, the 'degree of sedimentation' is derived from RGB imagery, which is not corrected by the thermal NUC calibration. Since RGB values are affected by varying illumination and camera auto-settings, they do not provide consistent surface reflectance measurements, and even if we remove the totally shaded areas, the issue of the

illumination remains. Therefore, developing a rigorous, normalized sedimentation index from these data is currently not feasible within the scope of this study.

10. Sect. 4.5: Belongs to summary and conclusions. There, it fits well at the very end.

AC: We agree with the reviewer and will move Section 4.5 to the Summary and Conclusions section, placing it at the end for better flow.

11. Sect. 5: I would expect some words regarding the correlations and the main findings resulting from them.

AC: We agree and will add a focused discussion on the correlations and highlight the main findings in Section 5.

Technical comments

AC: We thank the reviewer for the detailed technical and editorial suggestions. We are going to carefully review the manuscript to address all points raised. A few comments on points 17, 19, and 28:

- Point 17: We appreciate the reviewer's attention to detail. We have carefully considered this and note that temperature differences are consistently reported in degrees Celsius throughout the manuscript for clarity and consistency.
- Point 19: Thank you for pointing this out we are going to clarify that the RMSE for surface temperature decreased by 0.53 °C, down to 0.58 °C".
- Point 28 (Fig. 10): We believe this figure is valuable as it shows the range and distribution of calculated insolation values across the study area. While aspect itself may not be a primary focus, it provides context about solar exposure variability. We will clarify this in the text to improve its relevance and reader understanding.

1. Sun: "Sun" is a proper name and should be written with capital letter. It appears several times throughout the manuscript.
2. **P1, L13:** … our study (200x200 m) area → …our study area (200 x 200 m^2)
3. **P2, L26:** Wendisch et al. 2023 might be cited as well as it summarizes a huge project with its focus on Arctic amplification.
4. **P2, L53:** → …(), colder
5. **P3, L78:** Acronym
6. **P3, L85:** Which infrared? Near-, thermal-, far-?

7. **P4, Fig. 1:** Only Fig. 1a is needed. Figure 1b does not offer to many more details. If you prefer to keep both, add E(ast) and S(outh) in Fig. 1b and draw (a) and (b) into the Figures. I have overseen it for a long time. Furthermore, there is a missing space sign in the figure caption before (yellow rectangle).
8. **P4, L92:** Add an outline at the end of the introduction?
9. **P5, L115:** Size and time period are already mentioned in the sentence before. Skip the repetition.
10. **P5, L129:** Italic index, which might be a typo. Also, two lines later.
11. **P6, Table 1, caption:** Skip "used in this paper". Should be clear.
12. **P6, Table 1:** Maybe include some empty lines in between the different parameters. Since some parameters use two lines it is hard to see, which entries belong to the same parameter.
13. **P6, L136:** This last sentence belongs two the first sentence of this section. You should move it there. It will fit better.
14. **P8, L190:** back → black
15. **P9, Fig. 2:** The transparency is almost not visible on a printed version.
16. **P9, L214:** Here you jump over six figures to show something in a figure, which is not yet introduced. Please avoid this.
17. **P10, L247:** Differences in Kelvin, not in °C
18. **P14, Fig. 5:** … and boxplots (b) → …and (b) boxplots; actually I think that only one of the figures is needed. They more or less show the same.
19. **P14, L300:** to or by 0.53°C?
20. **P15, L320:** Fig.6a → Fig. 6a and the same for Fig. 6b a few lines later
21. **P15, L326:** … higher-resolution (10 s) sea… → … temporally higher resolved (10 s) sea…
22. **P15, L338:** better to use radiation instead of light.
23. **P18, Fig. 8:** Here, I have several things. (i) Uncommon Lat/Long values. I don't know how to interpret them. (ii) The colour bar is unintuitive. To me blue colours give the impression of lower snow depth, but it is the other way round. (iii) The scale ranges from 0 m to 0.6 m. Does it mean that there are parts with bare ice in the images?
24. **P19, L 398:** Missing brackets for the citation.
25. **P19, 403:** skip "and a small fraction of clean snow." It will be said in Line 405.
26. **P19, L405:** QGIS?
27. **P19, L 408:** RGB and in the next line R/G/B
28. **P21, Fig. 10:** Not really introduced and not really needed. What is the aspect?
29. **P21, L432:** flight legs instead of flight lines?
30. **P23, L453:** can't → cannot
31. **P23, L469:** Don't start sentence with an abbreviation.

32. **P24, Fig. 12:** Would be helpful to add a name list to the single figures. Maybe as a fourth column left or right of the graph, were you just write (vertically) All, Sediment, and No-Sediment.
33. **P25, L486:** … area of 200 m. → is no area
34. **P26, L500:** e.g. → e.g.,
35. **P27, L557:** … traps the light is a not so well expression. Try to avoid it.
36. **P28, Fig. 14:** Add All, Sediment, No-Sediment to the figures.
37. **P28, L568:** … the the …
38. **P28, L575:** Missing space sign in front of citation. Appears three times more within this and the next paragraph.
39. **P30, L627:** viable → sustainable?
40. **P32, Fig. A3:** x axis of graph b is incomplete.
41. **P33, Fig. A4:** (a) and (b) are missing inside the graphs. However, graph (b) is not really needed. It is already well visible in (a).

Reference:

Wendisch, M., et al.: Atmospheric and Surface Processes, and Feedback Mechanisms Determining Arctic Amplification: A Review of First Results and Prospects of the (AC)3 Project, Bull. Amer. Meteorol., 104 (1), E208–E242, doi:10.1175/BAMS-D-21-0218.1, 2023.