

In situ observed relationships between snow and ice surface skin temperatures and 2 m air temperatures in the Arctic

Pia Nielsen-Englyst, Jacob L. Høyer, Kristine S. Madsen, Rasmus Tonboe, Gorm Dybkjae, and Emy Alerskans

Summary

This study compares snow and ice surface temperatures derived from weather station radiometer measurements with air temperature measurements taken at the same locations. The study seeks to establish relationships between skin and surface air temperatures that can be useful for filling in gaps in the satellite record of surface measurements, and finds that the difference between T_{skin} and $T_{2\text{m}}$ varies by location, cloud cover, wind speed, and elevation. The results are potentially useful for improving estimates of arctic surface temperature change derived from satellite measurements.

General Comments

There is a clear motivation for the study, and the study is quite comprehensive in evaluating the effects of various factors on the observed relationships. The findings are important and potentially useful for improving estimates of arctic surface temperature changes. The text is fairly clear, but some improvements could be made in presentation of both figures and text. Some particular suggestions are provided below. I feel the suggested revisions are fairly minor overall.

The authors divide sites into different categories (ACC, UAB, LAB, SSC, and SICE), and these categories are shown in Table 1. These categories are useful and it would be helpful to the reader to be able to distinguish these different types of sites in Figures 1, 2, 5, 7, 10, and 14. For Fig. 1 for example, could the authors use different symbols for different categories of sites? In Fig. 2 sites could be grouped and identified as in Fig. 9. In Figs. 5, 7, 10, and 14, the colors are not particularly useful as it is hard to distinguish between the different sites. However, it would be useful to be able to distinguish between the different categories, possibly by changing the color scheme, so that the different types contrast with each other (e.g. all sea ice sites gradations of red, all SSC sites gradations of green, etc.), or perhaps the line style, line weight or transparency.

Table 2 is mentioned fairly late in the manuscript. Numbers from Table 2 could be mentioned earlier along with a citation to the table (e.g. in section 4.1 when discussing $T_{2\text{m}} - T_{\text{skin}}$ differences at different types of locations). This would help support the statements made when discussing the seasonal timeseries plots.

Section 5 seems to repeat many of the points mentioned in the results section. Perhaps the section can be reduced to avoid too much repetition of details, rather focusing on the general conclusions, and can be merged with the conclusions section, which is currently rather short. Some specific details, such as the discussion of the impact of the spectral range on measurements and the last paragraph of the discussion section might also be more appropriate to include earlier in the manuscript.

Specific Comments

1. P. 1, Line 17: Add “difference” after “<math><0.5^{\circ}\text{C}</math>”.
2. P. 2, Lines 9-13: Perhaps combine into two sentences to avoid shifting away from discussion of surface temperature.
3. P. 2, Line 32: Perhaps change “cooling of the surface” to “cooling of the surface relative to the air above it...” for clarity.
4. P. 3, Lines 20-22: The end of this sentence is confusing... it could just read “...and to quantify the differences between them.”
5. P. 3, Line 23: What is meant by “In the response to the latter”? Maybe remove this?
6. P. 5, Line 26: What is meant by “also reasonable” and “slightly off”? Please be more specific.
7. P. 5, Line 28: Again, please clarify “known to be wrong”.
8. P. 6, Line 6: Define “near surface” – a few centimeters?
9. P. 6, Line 22: I think “actual” can be removed from “actual observed”
10. P. 7, Lines 1-2: Perhaps here explain to the reader that this section provides some background on the energy balance that is important for interpreting results in the following sections. Otherwise the section seems out of place for the reader.
11. P. 9, Line 1: It would be good to be a bit more explicit here about why understanding diurnal and seasonal temperature variability helps interpreting satellite measurements.
12. P. 9, Line 3: Add “Greenland” after “Kangerlussuaq” for clarity.
13. P. 9, Line 7: Add the year range for clarity.
14. P. 10, Line 3: Suggest changing “yearly” to “seasonal” for clarity.
15. P. 10, Line 29: Add “for selected sites.” after “wind speed”.
16. P. 11, Lines 5-7: This sentence is not very clear. I think that the authors mean that a temperature inversion with a slope acts results in winds that reduce the magnitude of the surface temperature gradient, but it is not clear how this leads to the observed peak. The explanation later in the paragraph, that an inversion in conjunction with a slope produces winds seems clearer. In this case because the gradient produces wind, lower wind speeds are less likely at higher gradients. Can the authors clarify the statement here?
17. P. 11, Line 29: If the SICE sites have a larger frequency of overcast conditions, as stated earlier, how is it that they have only clear-sky observations between April and July?
18. P. 12, Line 12: Reiterate here that DMI_Q measurements are taken at 1 m rather than 2 m as for the other measurements, as this was stated much earlier in the manuscript.
19. P. 12, Line 15: Suggest changing “the results” to “the seasonal dependence” to make clear that the seasonal results are being referred to.
20. P. 12, Line 30: For what time period does the cloud cover fraction threshold apply?
21. P. 12, Line 31: What is the purpose of using these time intervals? Please briefly mention the reasoning.
22. P. 13, Lines 3-6: This sentence is confusing. It seems that longer periods are more likely to include clouds. Therefore, there is more likely to be a larger difference between “all sky” and “clear sky” conditions because the “all sky” conditions will include clouds.

23. P. 13, Lines 13-16: This sentence is also confusing... I think the authors are simply saying that the positive biases at some stations shown in Fig. 12 result from missing data. Please clarify.
24. P. 13, Lines 24-25: If possible, can the r^2 values be provided? This will help indicate how close the trends are to being linear.
25. P. 13, Lines 25-27: Given that the slopes at different stations, as well as for different types of stations are very different, how can the authors say that the results are “very encouraging”? While there may be a fairly good relationship between Tskin and T2m locally, it seems that coming up with a general relationship would be a challenge.
26. P. 13, Lines 26-27: Cloud cover and longwave radiation
27. P. 14, Line 17: Again, as in the results section, the statement that the wind “destroys its own forcing” is unclear.
28. P. 15, Lines 29-31: Again, given the difference between different sites, is this really possible?
29. P. 16, Lines 1-3: Although the results of this study are very useful and important, it seems that developing new products will require a fair amount of additional work to integrate the many different variables that can influence the relationship between surface temperature and surface air temperature, and account for the uncertainties in the observed relationships. The authors should make this clear here.

Technical Corrections

1. P. 1, Line 17: Change “particularly” to “particular”
2. P. 1, Line 24: Change “cloud limited Infrared” to “cloud-limited infrared”
3. P. 2, Line 18: Change “assessment of the climate change” to “assessment of climate change”
4. P. 2, Line 27: Change “due to the good spatial...” to “due to good spatial...”
5. P. 2, Line 29: Change “observations in the near...” to “observations and near...”
6. P. 3, Line 32: Add “and” before “lower ablation zone (LAB)”
7. P. 7, Line 7: Change “if found” to “is found”.
8. P. 8, Line 31: Suggest removing “in the Arctic” as it has been mentioned already.
9. P. 9, Line 23: Change “occur to be” to “are”
10. P. 9, Line 24: Change “except from EGP” to “except EGP”.
11. P. 10, Line 1: Change “but not reaches” to “but does not reach”.
12. P. 10, Lines 4-6: Suggest changing sentence to read: “Figures 6a-b indicate that the winter months have very little diurnal variability in the T2m-Tskin difference (as is also evident in Fig. 4), with an approximately constant difference...”
13. P. 11, Line 1: Add “data from” before THU_U
14. P. 12, Line 3: Change “Figure 11a-b” to “Figures 11a-b”.
15. P. 12, Line 19: Change “only be observed” to “only be utilized”
16. P. 12, Line 20: Change “in cloudy conditions” to “resulting from cloud cover” or something similar.
17. P. 13, Lines 3-4: Change “For e.g. the 72 hours...” to “For the 72-hour temporal averaging intervals, for example,...”
18. P. 13, Lines 11-12: Change “The orange graphs show...” to “Figure 5b also shows...”

19. P. 14, Line 9: Change “has the closest coupling” to “is closest to”
20. P. 15, Line 32: Spell out NWP.
21. Figure 6, caption: Change “Mean 2 m air temperature and skin temperature differences” to “Mean difference between 2 m air temperatures and skin temperatures for...”
22. P. 16, Line 3: Change “1980ies” to “1980s”.