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Interactive comment on "In situ observed relationships between skin temperatures and 2 m air temperatures in the Arctic" *by* Pia Nielsen-Englyst et al.

Anonymous Referee #2

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In situ observed relationships between skin temperatures and 2 m air temperatures in the Arctic
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Summary

This paper presents an overview of the relationship between the surface skin temperature and the 2 m air temperature over snow covered surfaces in the Arctic based on in situ observations. The rationale behind this is the satellite retrieval of skin temperature from satellite observations which are interpreted as being air temperature. This paper presents the processes that result in differences in the skin and air temperature over snow covered surfaces. I appreciate the fact that in this paper basically a review is given of these processes, but it is also the reason why I recommend to reject this manuscript, it does not present anything new. It does not present a recommendation on what to do to actually improve the interpretation of satellite products, it only states that these results might be helpfull.

Other reasons to reject are that the title suggests that the contents is about the whole of the Arctic, but the contents is limited to snow covered surfaces, and in addition also biased towards Greenland ice sheet stations. The results are thus not general applicable to the Arctic. I also found the writing often not clear, not consize, sometimes incorrect, and at some points I get the impression the author is not completely familiar with the involved processes.

What this manuscript needs is a clear recommendation that is directly applicable on satellite products, preferably to the whole arctic including snow free surfaces, and an actual application to a satellite product to show the impact of the difference between surface and 2 m air temperature on the satellite derived temperature.

To further help the improvement of the manuscript, a list of more specific comments and some technical corrections follows below.

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Specific comments

Title: either change the title to reflect the fact that you only look at snow covered surfaces, or extent your analyses to include the regions that are not (seasonally) snow covered

Present uncertainties. The spread in your results is large, but you do not present any uncertainty estimates.

Present your results with more confidence. There are numerous sentences that give me the impression that you are not absolutely sure about the result and processes. See for example in the abstract L14-19.

Abstract

You do not present any uncertainties in the presented numbers, while the results clearly show a large variability.
P1 L14-19: Present this differently: first describe the process, then the result. Thus first that there exists a very persisten surface based temperature inversion driven by radiative cooling.
P1 L21-22: Formulate more direct, this is not a new insight but already found for Antarctica.
P1 L24-28: Formulate more direct: this is basically the new result of your research. Start with the why this is so interesting, then the result. Leave out the last sentence. This should already be clear.

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Introduction

P2 L10: How does the Arctic contribute to mid latitude weather events.
P2 L28-29: Add what the rationale was of the other studies, and what the rationale is for this study. Being the first to do something is not enough.
P2 L23, P3 L8: I appreciate that you bring together all these different studies, but in the end you do not provide any new insights.
P3 L10: But you limit yourself to snow covered areas and periods only. This limits the applicability of this study in terms of the whole Arctic.
P3 L20: Reformulate, as far as I know Tskin is never observed, it is always derived from a radiative flux, not measured by a radiometer.

Data

How do you handle the different lengths of the time series? What do you present when you present averages? Period or Annual averages? Period averages might be biased to a certain season.
P3 L29: For the PROMICE stations why did you not include the stations in the ablation area? The processes there are similar to sea ice or melting snow surfaces.
P4 L1 (and for the other data sets as well): As far as I understood, you do not correct for the changing height of the sensors due to accumulating and melting snow. However, under strong inversion conditions, it is crucial to correct for height changes because it seriously affects your estimated temperature difference between surface and 2 m air temperature.
P4 L9: An albedo of 0.3 is already very low. How much do patches of snow free surface impact the results? And how much data is left when you filter these data out.
P4 L18: Are these measurement heights constant? The fact that it works better when taking the 1 m data is not a motivation to take the 1 m data instead of the 2 m data.

You should correct for height changes any way and recalculate all to 2 m, and when making a choice there must be a scientific rationale behind it.
P5 L5: Provide reference on which you base these conclusions.
P5 L17: How do you retrieve air temperature from these 'profiles'?
P5 L28-32: Here you state that you do not correct for height changes, but this impacts your results. You should correct for it, and at least discuss the impact on your results, and how this affects the uncertainty.
P8 L1-13: Not clearly formulated. What do you mean with 'cold sky'? And what are the 'sky effects'?
P8 L14: Why not present a scatter plot showing this, and provide more statistics, what is the Root mean square difference?
P8 L19: Please note that the cloud cover you derive this way is not the same as the cloud cover derived from visual inspection. Better use the term Long wave equivalent cloud cover (Kuipers Munneke et al., Int J. Climatol., 2011) Kuipers Munneke et al also describe the method presented here very clearly.
P8 L23: This relation varies from station to station. Why not use the observed Long wave radiation and air temperature to derive a relation for each station as done by van As?
P8 L26: How do you determine cloudy conditions? Different relation per station or not?
P9 L6-8: This is not correct. M is either 0 or positive, where positive energy is used for melting. When there is no melt, the ground heat flux G is responsible for heating AND cooling of the snow surface. In general, the snow surface will be below 0 in this case and water can refreeze in the snow pack. Rephrase.
P9 L14-16: Reformulate: use the term 'individual radiative fluxes' instead of 'large incoming ....'. Also be clear about what surface your are talking about. In this case you refer to papers all about the greenland ice sheet, but write also about 'ice growth'. That is confusing.
P9 L18: Incorrect. The surface indeed cools compared to atmosphere. This is due to the fact that the emissivity of the surface is about 1 while from the atmosphere is

0.6-0.7 depending on moisture content. As a result the surface will even cool when surface and air temperature are the same. In case of clouds the difference is much smaller.
P9 L8: Remove all parts relating to the direction of the wind. It is not of interest in this paper and what you describe is also very specific for glaciers and ice sheets. Furthermore, he 45deg is also incorrect, the angle depends on strength of temperature inversion and surface slope, and with that on wind speed itself. See Ball, 1960.
P9 L25-27: What is the difference between inversion and katabatic winds? As far as I know they are the same. Better use only one term. There is a difference in why a surface based temperature inversion develops that forces these winds, either because of a negative radiative budget or a surface that is limited in temperature to the melting point. In the later case the resulting wind is often referred to as glacier wind.
P9 L29: Effect of clouds is more complicated: clouds change the effective solar zenith angle, and it changes the spectral properties of the radiation, with that it changes the albedo and the amount of short wave absorption can actually increase. You do refer to this later in the manuscript.
P9 L32: Formulation: replace 'More transparant' with 'lower emissivity and with that absorptivity'.
P10 L1: Correct but also explain why.

Results

In presenting your results you illustrate the results with results from individual stations without motivating why you show a certain station. Furthermore, you basically have three different types of stations, ice sheet, sea ice and seasonal snow cover sites. I recommend that you present the results in terms of these three characteristics. This way you remove the bias in your presented results towards the Greenland ice sheet sites.
P10 L10: Please check the accuracy with which you present these results: three digits

is too much. Also note that these high correlations are not surprising since the annual temperature cycle is dominated by short wave radiation. It would be strange if the correlation was low. But you need to explain why the correlation is high.
P10 L13: Is it correct that the maximum in T coincides with max in Sin? Usually max in T is later than the max in Sin because Sin keeps heating up to close before sunset, usually resulting in a max in T later in the afternoon.
P10 L8: Why do you show one station as example? The strength of this paper lies in the large number of sites. Try to utilize that more, by presenting averages per different type of station (ice sheet, sea ice and seasonal snow, melting surface/non melting surface). Furthermore try to explain more and more often link to why this is important for the ultimate goal: satellite retrieval of T2m.
P10 L15: Explain why the largest variability is found in spring and winter.
P10 L22: Not surprising that EGP is the coldest, but explain why.
P11 L1-2: Not surprising as well, melt in summer limits the surface temp while local circumstances dominate winter. Explain.
P11 L5: I do not agree. In summer sea ice stations have a melting surface, in winter they are cold because they are further north. Not comparable to the coldest sites from Greenland. It is a combination of the melting sites on greenland in summer and the coldest sites in winter when latitude has the same impact as altitude.
P11 L10: Formulate more direct, this is not only probably, but very likely the effect of melt limiting the surface temperature. Range in spring and autumn is largest since it can already cool significantly at night, but still warms during day by the sun. Note also that this spring
and autumn signature is not restricted to arctic sites, nor snow covered sites.
P11 L11: Formulate more general: this also is true for the lower sites on Greenland, and in Spring for the seasonal snow cover sites. For any snow surface that is melting in summer.
P12 L6: Why don't you show a figure with the annual cycle in temperature inversion for all sites similar to figure 4 and 5? Then combine 4, 5 and Tinv figure into 1 figure

with panels a-c. That provides more information on whether the mean annual cycle is biased to a certain type of stations, for example the Greenland ice sheet sites, and the lack of sites with seasonal cover. Note also that seasonal snow covered areas have in spring the same signature as sea ice and greenland margins, but not in autumn, since it does not have snow yet. That will affect this relation, and cannot be judged in the presented figure.
P13 L8: Peak in the diurnal cycle of what parameter?
P13 L10: Describe more in processes besides stating what can be seen in the figures. In this case: At night net radiation is negative thus cooling the surface.
P13 L11: Explain why Tinv is generally higher at KPC_U compared to KAN_U, explain.
P13 L11-12: Again, not surprising, since the processes are the same, but explain why it is similar.
P13 L14: Rephrase. The term 'due to' does not explain the link between wind speed and the turbulent fluxes.
P13 L17-18: Rephrase, it is not the elevation that determines the wind speed for Greenland, but the slope. Stronger radiative cooling does not necessarily result in higher wind speeds. Flat terrain there is no link between them.
P13 L19-20: Explain!! These are all sites for which the wind is determined by large scale synoptice conditions combined with local topography, while the Greenland sites the wind is localy generated based on surface slope and inversion strength. Thus totally different origins and signatures.
P14 L3-4: Reformulate and make sufficient reference to existing literature. The relation between inversion and turbulent mixing is well known.
P14 L5-9: It would be much more interesting to show something like net radiation in colloring instead of counts. You also do not need to binn the data for that but simply show scatter plots. You only need to bin to calculate the mean. Furthermore, this information is all caption information and not necessary to put in the main txt.
P14 L9-10: Refering to figure 9, why not make plots of the different type of stations combined. Thus a plot for the greenland station, another for the sea ice stations and

the last for the seasonal snow covered stations. And then explain the different signatures.
P14 L13: Rephrase sentence. Stress the local maximum , not the minimum below 2.5 m/s. Thus turn this sentence a bit around.
P15 L6: When refering to the PROMICE sites explain that it is basically all sites with a surface slope where a katabatic flow develops.
P15 L6-7: Remove the part about comparing the temperatures and rephrase: and was also found by Adolph et al, 2017 for the summit station. (Not that it would be strange if Adolph had found something else than you, since he/she uses the exact same data!!! However, since this is a feature likely katabatically forced I am surprised you also found it for summit, or has this site still a sloping surface?
P15 L11-17: Rephrase this. Not necessary to explain how they studied this, this is also not unexpected but known phenomena and it is also not surprising but to be expected to see this for Greenland as well. There is basically no difference in the inversion winds for Greenland or Antarctica, processes are the same. Only difference is that Greenland is located a bit closer to the equator and also has sites where the melting surface restricts the surface temperature creating an inversion instead of only a negative radiation budget.This bit gives the impression that you are not familiar with the processes.
P16 L6-14: Remove the part relating to wind direction. For the general discussion, I do not see the point in discussing the wind direction. It is very specific on an ice cap, while here your goal is to be much more general in aid of satellite retrieval.
P16 L10: I do not agree that 10b supports the hypothesis. Basically all vallues of cloud cover are with this wind direction, which is to be expected since most of the time the wind is katabatic, downslope. Remove the link with cloud cover here.
P16 L12-13: It is correct that less clouds result in more cooling (in winter) but from the figure the same wind direction also has the highest cloud cover, thus what does this tell us?
P16 L13-14: In my opinion these results do not support the Hudson and Brandt result.
P16 L15-17: This is something you should mention much earlier, since it compromices

your general discussion.
P16 L21: Please explain why you want to estimate the bias: Something like: in aid of satellite retrieval, the retrieval is done using clear sky conditions only, this is therefore not the average inversion strength, we define the bias here.
P17 L4-6: Please explain why. Only stating what we can see in the figure is not sufficient.
P17 L9-10: Explain why you look at these individual sites, but better to group them given certain characteristics. (ice sheet vs sea ice vs seasonal snow covered regions.
P17 L10-11: Again: explain, only stating what we see is not enough.
P18 L1: Bin size of what? Explain.
P18 L3-6: Also note the large spread! This makes generalizing the results almost impossible. You have to remark on this.
P19 L11: Explain why and is this significant given the spread in different sites?
P19/20 L17/L1: What is it that is generally derived from satellites? Tskin or T2m? In case of Tskin, you do not need the whole discussion about inversion strength. In case of T2m, it is important! Please introduce this better.
P20 L2-3: What do you mean by 'given time window'? Time window of the gap? Is there a linear interpolation to fill the gap? Or are averages determined over a given window assuming how many satellite retrievals to be necessary to be representative for that period?
P20 L3-5: Thus 2 issues: the bias resulting from only using clear sky observations, and the impact of averaging over given time window on the retrieved temperature: Rephrase to make this more clear.
P20 L7-8: What is the uncertainty? The spread is enormous, so are the values significantly different?
P20 L8-10: Explain! For example: how does this relate to the way cloud cover is determined? Cloud cover from LWd is not the same as the visual determined cloud cover! How is cloud cover marked in the satellite images? And why the strange differences between 24, 72 and month?

P20 L15: Explain the positive bias over sea ice in spring.
P20 L18-19: Regarding your statement 'which may.... bias observed' You have the data to confirm this, to test what the impact is of the omission of certain seasons. Please do so.
P21 L6-9: I don' understand what you want to say in this sentence? what does the determination of cloud cover has to do with the T2m determination? That is based on Tskin anyway. Reformulate to make more clear.
P21 L13-14:Relating to the FRAM stations: What is the conclusion? Explain.
P21 L15: Please also present uncertainties! Is the slope presented here significant?
P21 L15-16: Can be useful is rather a weak conclusion. Much stronger to come with a clear recomendations, else you only present known phenomena.
P22 L3: I have a preference of integrating the discussion in the result sections. That way you do not need to repeat the results here and immediate can answer the questions arising from the presented results. The Discussion section than only contains an additional discussion based on all results.
P22 L5-7:First present an explanation, then state that others found the same thing.
P22 L10: Present uncertainties in the numbers.
P22 L19-21: Nothing new, please reformulate: Keep it simple and more professional: The relationship is more complicated over sloping terrain.....
P23 L4-7: Reformulate, does not explain anything: what you want to say is that the inversion combined with slope results in a flow which actually destroys its own forcing. As a result there is a optimum in inversion strength and wind speed. Which was also found by Hudson and Brandt.
P23 L10-13: Why would Greenland be different? Physics does not change! You even see katabatic winds on much smaller ice caps. Physics is the same, thus the same conclusions.
P23 L14-18: This is a repeat from the results section. Try to prevent that as much as possible.
P23 L25: Why not show a scatter plot showing the relation of Tskin determined by the

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two different methods. Should be as much as possible on a 1-1 line. Then it is easy to say that the presented results are similar.
P23 L31-32: Rephrase the sentence 'In general... time interval'. The sentence is confusing.
P24 L8-10: Rephrase: satellite skin temeratures are often compared to 2 m air temperatures, not the local skin temperatures. Remove reference to 'surface' air temperature.
P24 L16: I do not agree that you present a wide range of weather conditions: Your presented results are strongly biased towards the Promice Greenland stations, and you present only limited number of seasonal snow cover sites.
P24 L18-22: I had hoped for a stronger conclusion. For example what do you need to do to correct a satellite retreived Tskin for T2m?

Technical corrections

Introduction

P2 L17: Replace 'important' with 'sensitive'.
P2 L23: Formulation is not correct or confusing: there are four radiative flux components, not two. Rephrase.
P3 L19: Remove 'to assemble.... study'.

Data

P3 L27: Figure 2 is presented before figure 1. Figures should be referenced in order consecutive order.
P3 L30: Provide sensor information. You do that for other data sets as wel, or remove the sensor information from the main text and provide in a table.

P5 L28-32: Move to start of data description section. (P3 L21)
P9 L22: Replace 'where' by 'when'.

Results

P10 L13: Check your use of colder / warmer versus lower / higher. Tskin is lower than T2m, not colder.
P14 L3: Remove sentence: 'This section... to wind.' Rather obvious.
P14 L5-6: Remove sentence 'the number ... (red curve).' Not of interest.
P14 L11: Replace 'gradients' with 'difference'.
P14 L12: Replace 'can sometimes be' with 'is'. Formulate more direct.
P14 L12: Replace 'complicated than that' with 'complex'.
P15 L6: Replace 'for' with 'to'.
P15 L7: Replace 'find' with 'also found'.
P15 L8: Replace 'using' by 'at Summit based on', and remove 'at summit' at the end of the sentence.
P15 L9-10: Rephrase: Also at .... wind.' With 'Furthermore, Hudson and Brand (2005) show that at south pole the maximum inversion strength occurs at wind speeds of 3-5 m/s. They suggest that it is not the weak wind promoting the strong inversion, but the inversion forcing the air flow resulting in an katabatic wind.
P18 L1: Replace 'considering' with 'for'.
P18 L2: Remove 'the obvious feature is that'.
P18 L3: Replace 'from' with 'due to'.
P18 L3-6: Not necessary to mention 'considering all observations/sites' three times in one sentence. Remove.
P20 L10: Insert 'monthly' between 'the' and 'mean'.
P20 L11-12: Remove 'averaged for each month'
P20 L14: Replace 'may be a result of' with 'can partly be explained by'
P22 L22: Remove 'a few', replace 'in' with 'for'.

P22 L22: Add reference to Adolph et al for GrIS.
P23 L1: Remove 'The feature...Adolph et al., (2017)'.
P23 L1: Reformulate 'It is likely that this feature..' by 'This feature can be explained by the forcing of a katabatic wind by the surface temperature inversion.'
P23 L2: Remove 'persistently....terrain'. (remove all reference to wind direction)
P23 L3: Remove 'but also other factors such as'.
P23 L4: Remove 'coriolis force'. Coriolis only changes the direction of the wind, does not have impact on the strength.
P23 L7-9: Remove 'We find that..... at the surface'. (remove all reference to wind direction)
P23 L12-13: Remove 'More research... vice versa.'
P23 L18: Replace 'The explanation is that' with 'The smaller inversion strength under cloudy conditions is explained by the fact that '
P23 L18: Remove 'in the Arctic'
P23 L20: Remove 'the T2m ...Tskin instead.
P23 L22: Replace 'that finds' with 'who found'
P23 L24: Replace 'are' with 'is.
P24 L5: Replace 'thought to play an important role in' with 'factors (partly) explaining the'.
P24 L15: Replace 'gathered' with 'used'.
P24 L17: Remove 'Historical and present..... T2m observations'. I do not understand this statement.

Figures and tables

Table 1. You incorrectly classify the arm stations as land ice. They should be classified as seasonal snow covered.

Table 2. I am missing an indication of variability. The spread as show in figure 13 is enormous!! This should be visible also in these results. Furthermore, I also think you should not put the ARM sites and sea ice sites together. Very different characteristics. 3 categories: sea ice, land ice and land!

Figure 3: Use different y-axis for Temperature and temperature difference. In the present figure, I cannot see the cycle in the temperature difference.

Figure 6: present the standard deviation as a band of uncertainty around the mean. And explain what the standard deviation indicates: variability between stations of between different years? Or both?

Figure 9: I am not really interested in counts. This figure can be much more instructive when presented as a scatter plot of Tinv as a function of wind speed with coloring of the net radiation. The mean can be plotted in the same figure as a black line and the standard deviation as 2 extra dotted lines around the mean. And the lower plots can be left out.

Figure 10.: Remove figure. Not interesting in the scope of this manuscript to discuss relation with wind direction.

Figure 15: What is the variability in the averages? You can introduce lines that indicate the standard deviation. Explain how you make these averages. Are these averages over all observations? or have you first made annual averages? Could there be a seasonal bias as you explain for DMI_Q

Figure 16: For me it is more logical to present this in 3 categories instead of 2. (Ice sheet, sea ice and seasonal snow covered.) Present the standard deviation as a band around the mean. What do the standard deviations represent? only variability based on the different stations? Or also an indication of interannual variability?

References

Note that the international custom is to list surnames starting with 'van' under 'v' in the alphabetical order.

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