The Cryosphere Discussions

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Comment on tc-2021-211

Anonymous Referee #3

Referee comment on "Offset of MODIS land surface temperatures from in situ air temperatures in the upper Kaskawulsh Glacier region (St. Elias Mountains) indicates near-surface temperature inversions" by Ingalise Kindstedt et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-211-RC3, 2022

Review of: Evaluating sources of an apparent cold bias in MODIS land surface

temperatures in the St. Elias Mountains, Yukon, Canada

Kindstedt et al. submitted to the Cryosphere.

December 22, 2020

This manuscript should be rejected for publication.

General comments:

The major finding seems to be the difference in air temperature and glacier temperature is the result of an inversion. Surface temperatures of snow and ice are usually colder than air temperatures. This is particularly true during the melt season and is a pretty well established fact. I am unsure what this manuscript offers that is not already present in the literature.

The aims and goals should be refined and better described in the manuscript. The organisation of the manuscript requires substantial revision.

No lapse rates are reported, which is the typical way to identify an inversion.

Editing for clarity is required. Details need to be added to the many vague statements in the manuscript.

Typically these sorts of studies use orders of magnitude more data than what appears here. An argument needs to be presented that the small data set is adequate. Static (or literature) values need to be replaced with measurements where possible.

The placement of figures in the narrative is disjointed and not logical. Many results are being presented in the discussion.

Many references concerning the relationship between energy balance and glacier mass balance are missing.

There is substantially more meteorological data available than what has been used in this analysis.

Specific comments:

Abstract:

MODIS LST can also be sparse or absent

MODIS LSTs are offset… which each LST measurement, average LST, minimum, maximum…

Footprint usually refers to swath width, or some derivative. Is it the grid cell size you are referring to?

Snow emissivity is >0.8 and can be close to being a blackbody, so it is intuitive that brightness temperature would also contain bias.

Line 21: …with far reaching impacts. This is the kind of statement that the manuscript is peppered with and is virtually meaningless: please revise, here and throughout.

Line 23: reduced the Earth's albedo, further accelerating warming. Please provide credible references for this statement. Most studies do exactly what you are doing which is confusing correlation and causation. Perhaps as the temperature increases more snow is melted, and the newly exposed area provides a negligible amount of atmospheric warming. For context read: https://www.nature.com/articles/s41598-018-27348-7.

Alternatively, the reduction in snow and ice causes a warming, but the amount of increase in temperature cannot be disentangled from warm air advection.

Alternatively, the snow albedo feedback melts glaciers pretty efficiently.

Line 23-24: As written this statement is not correct. Hugonnet

et al.(2021) didn't analyse albedo, nor was it mentioned in Zemp.

Line 25: Some ink should probably be spilled on your geographical definition of the Arctic. From a climatology point of view (i.e., Arctic Amplification) Arctic is defined as north of the Arctic Circle.

Line 29: I don't know how many crucials and criticals I have seen to this point. The writing will pack more punch if these types of words are used substantially less often.

Line 32: controlled by atmospheric warming: not necessarily true, these might simply be correlated.

Line 33: continued -> projected?

Line 34: delete "to be able"

Line 38: What does "Remote sensing temperatures include the final surface temperature" mean?

Line 44: high temporal resolution and long temporal record; they provide two decades… what resolution, which decades? Always provide dates, rates, numbers, values, colours, weights, dimensions, etc. when describing quantitative subjects.

Line 59: "Lower elevation sites receive moisture from different air masses" detail why this is important

Line 65: Not necessarily a universal phenomenon: see:https://link.springer.com/article/10.1007/s00704-012-0687-x.

Line 71: "surface itself" should be replaced with details like where the photons are being emitted e.g., from the top x nm of the snow and ice, etc.

Line 75: This paper is relevant here: https://journals.ametsoc.org/view/journals/clim/26/5/jcli-d-12-00250.1.xml

There is probably only a very minor contamination issue.

Line 77: Summit should have Greenland appended to it, here and elsewhere, when referring to the summit of GIS.

Line 80: More detail is required here: There is more forcing that downwelling solar. Air parcel advection plays a role. And why does it have to be balanced- the temperature might be changing? Provide rationale.

Line 82: efficient emitter than the atmosphere - implies the atm has a lower emissivity than snow surface. Provide details. Atmospheric emissivity is mainly dependent on water vapour concentration.

Line 92: pixel is a picture element of a computer screen, where the minimum resolution is set by the screen parameters. Using pixel to describe a remote sensing array element or grid cell is common usage, but not technically correct.

Line 96: How exactly would "disparate changes in emissivity" lead to a bias? Provide details.

Line 108: There are records longer in the Tibetan Plateau and on Greenland and very possibly elsewhere. For some context see: Global Historical Climatology Network Monthly—Version 3 (GHCN-Mv3) (www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-monthly-version-3). The GHCN-Mv3 ftp server provides a list of weather stations (ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v3/products/ghcnm.v3.first.last) with associated country codes, station location, elevation, and data duration.

Figure 3: Landsat has different sensors (MSS, TM, ETM+, etc.) so either break these up in

the figure or identify differences in the text/caption, or both.

Line 119: Is air temp. samples on the hour of hourly averages of sub-hour measurements? MODIS LSTs are essentially samples.

Line 122: Not correct. As snow level changes the Divide sensor's height above the surface will change. It is possible that it also gets buried in some of the winter months.

Line 124: "plastic container"? Provide details. Was this vented passively? Exposed to direct sunlight?

Line 125: We combine the Eclipse AWS and iButton datasets… Why? Is this a valid method? Provide sensitivity analysis.

Line 126: consistent. - define, preferably statistically.

Line 130: "employ an improved method" provide details and why relevant here.

Line 135 (and below): It appears results are provided before methods have been described. It is not clear what is being compared. Is it daily averages of air temperature? Have temperatures (air and MODIS) been temporally matched?

Line 141: "This may be due to the inclusion of the warmer nunatak surface" - this is testable by comparing time series from grid cells which contain less (or none) exposed rock.

Line 144: What is the rationale for using only <30 degrees view angle? Is there a sensitivity analysis or a citation to confirm this?

Line 145: This temporal subset will sample somewhere below the maximum daily temperature. This also seems to be a very small amount of data from what should be available from a 20 year time series, from two sensors and multiple daily overpasses.

Line 146: "The average time between scenes" describe what this means and why it is important - as written I have no idea what it means.

Line 151: Removing these data ?

Line 160: Under development as of when?

Line 167: TOA Tb is not really a useful metric to compare to surface temperature.

Line 170-175: Provide bounding values for “low” and “high”.

Line 176: “would” -> could.

Line 176: What does “physically plausible under surface conditions” mean exactly?

Line 177: “theoretical model of temperature inversions.To” - Provide details and a space after the period.

Line 185: Typically the terms you avoid are small compared to the dominant terms you include. Provide a range of values for all the terms. This will allow the reader to evaluate the effect of removing some terms.

Line 188: It rained at the summit of Greenland Ice Sheet this year, so probably better to rephrase this sentence.

Line 195: Why assume En=0, when it will most certainly not be, either seasonally or annually?

Line 200: Provide range of values for atmospheric emissivity.

Line 200: ERA 5 Land produces a downwelling longwave variable. Why wasn't this incorporated into the analysis?

Equation 3: Provide more information about how this equation was derived. And why use a literature value for albedo? There is considerable variation, spatially and temporally, in albedo. Why not use the coincident MODIS albedo?

Line 203: MODIS provides emissivity values. What are these for the given days sampled in this study? What are the seasonal ranges of snow emissivity?

Line 208: Differences between median values? I am unsure what "Median differences" is.

Line 209: Which is warmer, surface or air? Not clear.

Line 210: Are these distributions normally distributed? There are tests to determine this.

I gather that seasonal averages use all of the data from 2000-2020. Are air temperature and surface temperature changing at the same rate? Are inversions weakening over time? Are rates of temperature change similar between seasons? Is there a monotonic trend in emissivity? All of these things will influence your results.

Line 223: Temperature has not been measured to the precision being reported.

Line 247: $R^2 = 0.02$ is statistically significant? How big was this data set?

Figure 5: I am not sure what the point of this figure is? The two MODIS thermal bands will differentially absorb in the atmosphere, which is the basis for the split window LST algorithm. To work out the atm. emissivity, atm. column water vapour is required.

Figure 6: Are these data temporally matched? It must be sampled data because a daily average of 1000 w/m^2 is not feasible.

Line 263: "averaging temperature" - means what?

Line 266: Air temperature scales over 100s of km, so not surprising.

Figure 7: I am skeptical about the magnitude of the p-values reported here. These should be checked.

Line 275-277: Why would you expect this? Make sure all of the expectations in this section include enough background information for a reader to evaluate.

Figure 9: Earlier in the methods you said the time of MODIS capture was between 11AM and1:30PM. Why the different diurnal time range here? Same issue with Table 6.

Line 289: “suggesting that emissivity values during these seasons may contribute to the offset” - how exactly?

If there is a trend in cloud cover change then both downwelling shortwave and longwave radiation will be altered over the course of the study period. This could add a substantial amount of error to the results. This needs to be analysed.

Line 295: which changing surface conditions?

Line 315: Why was a simple energy balance model used when radiosonde or re-analysis data can be used to determine inversion depth?

Line 314: “wintertime temperature inversion” level? Williamson et al. (2020) put inversion level at approximately 1200 masl. The two stations used here are 1000 to 2000 m above this level, and are not situated in valleys where cold air drains and collects.

Line 367: “Surface melt is primarily driven by high air temperature” - what is high? And melt is correlated with air temperature. There are many examples in the literature of melt

rate being influenced by short and longwave radiation.

Line 369-370: MODIS albedo correlates very well to glacier mass balance. There are many examples of this to be found in the literature. MODIS can't measure albedo under cloud cover. I am not sure the statement presented in the manuscript is correct.

Figure 10: Corrected is the wrong word. LST and air temperature are not the same thing and should display offsets. These offsets are important for understanding the energy transfer between surface and atmosphere. If the goal is to produce air temperature fields originating from MODIS LST, then 'converted' instead of 'corrected' might be a better option. Further, there are many examples of methods to convert LST in the literature, most of which do not appear in the manuscript. The AWS data from 2020 is suspiciously cold.

Line 376: Snow and ice melts when its temperature reaches 0C not when the air temperature above it reaches 0C. So the rationale here needs to be revisited.