

Review of: “Recent North Greenland temperature warming and accumulation”, by H.A. Kjaer et al., submitted to *The Cryosphere*.

The authors present accumulation and temperature time series from two new data sets. These include six firn cores (sites 2015T-A1 to A6) from the 2015 N2E transect crossing the major northern Greenland ice divide from NEEM (northwest) to EGRIP (northeast), and eight snow cores (sites WP’s) from the 2017 Windsled Project transect extending to the southwest of site EGRIP. These data sets are evaluated using a combination of previous snow and firn cores extracted in the vicinity, overlapping radar measurements and outputs from the regional climate model HIRHAM5 forced by climate reanalysis. Using these data, the authors find an east-west gradient with high accumulation on the western part of the northern ice divide, further decreasing at the crest and towards the eastern side of the divide. Based on these measurements, the authors find a warming trend of 0.9 to 2.9°C per decade in north Greenland over the last 20 years, that is not associated with a positive trend in accumulation, as would be expected from a Clausius-Clapeyron relationship.

While the paper presents important new data that will be of high interest for the community, the novelty of the results compared with previous work is unclear. The contributions of this work should be stressed and clarified. The authors quantify recent trends in accumulation and temperature in north Greenland. However, these core results are not supported by dedicated Tables or Figures. In addition, the authors describe a “foehn” effect on the major ice divide of north Greenland, i.e., with higher precipitation on the western windward slope and drier conditions on the lee-side, without ever explicitly naming it. The paper is dense, sometimes including non-essential information that are hardly discussed in the paper (e.g., deuterium data set), and the manuscript lacks a clear structure and storyline. Tables and Figures are not called in order of appearance, forcing the reader to jump back and forth from one to another. Therefore, the manuscript is sometimes hard to read and the reviewer deems that **major revisions** are necessary before publication in the *Cryosphere*. The authors can find the reviewer’s comments below.

General comments

- 1. Novelty:** The authors should clarify the objectives and novelty of the study compared with previous work. The authors quantify trends in accumulation and temperature in north Greenland, but these results are not illustrated by figures or tables with trend estimates. Figure 2 shows time series of accumulation at the six new firn cores but without trend lines; there is no Figure/Table discussing trends in temperature. The authors refer to previous work and do not provide significant new insight on accumulation/temperature trends in north Greenland. The authors also describe what seems to be a “foehn” effect on the major ice divide of north Greenland, but never discuss the phenomenon as such. In addition, an important message, i.e., accumulation does not increase with temperature following a Clausius-Clapeyron relationship, is not discussed except in the Abstract and Conclusions.
- 2. Data description:** The authors should more clearly describe and locate the many data sets used in the manuscript. For clarity, the authors should use consistent labels for their study sites. For instance, the firn core sites are sometimes referred to as 2015T-A1, or A1, or in L14 of P8: T2015-A4, which is confusing. In addition, the authors should clearly mention that B-19 to 30 sites are from the NGT transect; this is not explained in the text or in any caption. More importantly, the authors should locate the new sites on a Greenland-wide map (e.g., as in Fig. S2) and show the accumulation map in Fig. 1 as a zoom in on the study region. Figure 1 is also hard to read with the many sites shown, and overlapping labels; some sites are not shown or labeled, e.g., N2E02-N2E22 mentioned in L8 of P7.
- 3. Consistency:** The authors should be clear and consistent, e.g., with units, when referring to study sites or discussing temporal trends/spatial patterns. For instance, accumulation is sometimes expressed in m, cm or mm w.e. per year. Please, select the most relevant unit and convert all numbers accordingly across the manuscript. This also holds for (firn) cores sections sometimes expressed in m or cm. The paper uses terms that are not well defined (e.g., NGT, ultrapure milliQ, Danish bag) or acronyms that are not consistent (e.g., EGRIP and EastGRIP, see also General comment #2). In the discussion section, the word “trend” is used both for spatial patterns and temporal fluctuations of accumulation, which is confusing.

4. **Display:** The display of Tables is really poor, making them hard to read and interpret. Tables caption do not always describe all the information listed, e.g., uncertainty values in brackets in Table 2. The information shown in Table 3 is unclear. In Figure 2, it is almost impossible to discriminate the “Schaller snow core” line from the HIRHAM5 ones. Figure 2 could also use more contrasted colors than light green and yellow, which are hard to differentiate.

Point comments

L20 P1: Accumulation measurements are scarce all over the ice sheet, this is not specific to the north.
L25 P1: Do the authors mean sublimation instead of evaporation?
L3 of P2: The reviewer is concerned about the “ground truth” wording. All observations come with uncertainties and are thus not “ground truth”. Please replace “ground truth data” by “measurements”. This holds for the whole manuscript.
L19 P3: Explicitly state “precipitation minus evaporation” or sublimation. See comment in L25 P1.
L23 P3: Describe the cores (name) and refer to an overview map for their locations.
L29 P3: “0.55 cm section”
L34-35 P3: The sentence is unclear, please reformulate.
L38 P3: Same as in L23 P3, “eight deep ice cores core drilling sites (WP... in Fig. 1) sampling the upper”
L32-35 P4: The deuterium time series is hardly discussed in the manuscript. This could be removed together with Fig. S3c, L40 of P8 to L7 of P9, and L11-13 of P9.
L24 P6: Do the authors mean “in line with previous estimates” instead of “within uncertainties”?
L28 P3: The authors could use skin temperature from HIRHAM to verify this statement.
L29-35 P6: Please provide relevant references about the following statements: 1) HIRHAM has a warm bias in winter and does not resolve strong temperature inversions, 2) HIRHAM has errors in its cloud parameterization, 3) HIRHAM poorly represents turbulent exchanges.
L20-26 P7: This paragraph is unclear. The authors should better state that the model overestimates or underestimates accumulation by XX%, e.g., in L22 “model accumulation is underestimated by 34% ($R^2 = 0.69$)”. The same holds for the whole paragraph. In L22, $R^2 = 0.69$ while the regression slope is 0.74.
Section 3.3: The structure of this paragraph could be improved. After discussing the representativeness of point measurements by a HIRHAM5 grid cell in L30-35 of P7, the authors could first discuss spatial correlations (L2-15 of P8), then comment on small scale topographic impacts (L36-42 of P7), and further conclude with L15-18 of P8.
L35 P7: This sentence is unclear, please elaborate.
L3 and L10 P8: “Table 4”. L30-31 P8: This sentence is unclear, please reformulate.
L20 P9: Could the authors provide both the trends of the last 2 decades and that of RCP8.5?
Section 4: The authors should consider listing relevant accumulation/temperature trends in a Table to support the discussion.
L4 P10: What do the authors mean by “extreme accumulation”, how is this quantified?
L6 P10: “Table 3”. L17 P10: “pattern” instead of “trend”.
L23-25 P10: What is the influence of the camp site? Is this paragraph essential to the discussion?
L35-38 P13: This is an interesting point but unfortunately not discussed in the paper.
L8-9 P14: Where does this correlation come from? It has not been shown or discussed earlier.

Stylistic comments

L35 P1: (McGrath et al., 2013); L17 P2: “equivalent to a 10%” ; L20 P2: (2012) ; L28 P2: “a need for additional measurements” ; L42 P2: Add “(H₂O₂)” after peroxide. L3 P3: “reconstruct annual accumulation layers”. L6 P3: “has” ; L39 P3: “were” ; L4 P4: “followed the same” ; L29 P5: “from” ; L27 P9 : “triangles” ; L33 P9 : “agreement” instead of “comparison” ; L35 P 9: “mostly” instead of “more often than not” ; L23 P11: “in 2010 at 2015T-A2 even in HIRHAM5 model results.” L26 P12: “were” ; L19 P13: “To accurately resolve spatial patterns of accumulation ...” ; L31 P13: “thereafter” instead of “from the millennia onwards” ; L13 P14: “previously”. L11 P21: “Significant correlations are shown in bold ...” ; L8 P23: “solid black line”

Figures & Tables

Table 3: It would be interesting to show the correlation between accumulation measured at a site and modelled for the closest HIRHAM grid cell, i.e., a second value on the diagonal of Table 3.
Figure 2: Lines could be displayed with more contrasted colors.

Figure 3: Since site 2015T-A6 is located between 2015T-A3 and 2015T-A4, it could be shown as such. The comment holds for tables and other figures.

Figure 4: This could be moved to the Supplementary Material. The same holds for Table 4.

Figure 6: Is this a major result? The figure could be shown as a sub-panel of Fig. S2.