The Cryosphere Discuss.,
doi:10.5194/tc-2016-201-AC1, 2016

The Cryosphere
Discussions
Open Access

Interactive comment on "Rapid Wastage of the Hazen Plateau Ice Caps, Northeastern Ellesmere Island, Nunavut, Canada" *by* Mark C. Serreze et al.

Mark C. Serreze et al.

serreze@nsidc.org

Received and published: 7 November 2016

Editor, The Cryosphere:

Responses to the comments and suggestions to the first anonymous reviewer of manuscript tc-2016-201 Rapid Wastage of the Hazen Plateau Ice Caps, Northeastern Ellesmere Island, Nunavut, Canada, follow below. We appreciate the efforts of the reviewer, who clearly spent a great deal of time with this manuscript and as a result have greatly improved it.

Respectfully,

Mark C. Serreze

Director, NSIDC University of Colorado Boulder

Reviewer #1

Comment:

This paper documents the near demise of 4 small ice caps in NE Ellesmere Island - ice caps that have a >50 year history of study. The paper is of some interest because of this long history, but it could be made more interesting if more effort were made to place the results in a broader regional context.

Response:

We thank the reviewer for his/her obviously very careful read of this paper. We agree that the paper needed to better place the results into a broader context. We have attempted to appropriately respond to the reviewer's comments and recommendations that follow below.

Comment:

Specifically, there is no mention at all of the work of Gabriel Wolken, who used trimline mapping to document the pattern of post Little Ice Age glacier retreat across the Queen Elizabeth Islands and interpret observed patterns in terms of past climate dynamics (The Holocene 18 (4), 615-628 and 629-641, 2008). Nor is there mention of the chapter on this region in the GLIMS book (edited by Jeff Kargel and others; Global Land Ice Measurements from Space, pp 205-228 (Springer, 2014)), which provides a sub-regional breakdown of post 1950's ice retreat across the area as a function of initial ice cap/glacier size. Many small ice caps have disappeared from this region in the past 60 years, but this would not be obvious from reading the submitted manuscript).

Equally, there is no reference to the 4 in situ mass balance time series from the area which provide a nice picture of the short term variability in climate-mass balance linkages that would help with the interpretation of the results presented here - or of the regional ice mass change time series from GRACE, which would do the same thing. The relevant data are published annually in the Arctic section of the BAMS "State of the Climate" report and are readily available (as are the mass balance time series from WGMS). Nor is any comparison with ice core records from the region, which would also help to provide longer term context for the work (e.g. Fisher et al., 2012, Global and Planetary Change 84, 3-7).

As a result, the paper seems somewhat disconnected from what is already known about post LIA and recent glacier change in the region and its drivers. I think this issue has to be addressed if the paper is to pass the "significance" test for publication in The Cryosphere. The paper does nicely document the history of these specific ice caps in more detail than would be possible for most others in the same region (hence good for originality) , and the detail is sufficient to allow reasonably sophisticated comparison of ice cap retreat rates and patterns with other climate and mass balance indicators for the region - but this is not really attempted (hence fair for scientific quality and significance). This leaves the paper with a rather anecdotal feel. I think this needs to be changed before I could recommend publication in this journal.

Response:

We have attempted to place the paper into the broader context of existing research. Note that Reviewer 2 pointed out the same shortcoming. First, to help set the stage, the first sentence of the second paragraph of the introduction how highlights out intent to place the results into better context:

"This paper documents the behavior of the Hazen Plateau ice caps over the past 55+ years in the context of other glaciological studies in the Canadian Arctic." Next, and importantly, some reorganization was necessary. Specifically, the summarized history of change that was a the end of Section 2 (Previous work) was moved to the end of Section 3.1, and expanded to include a fuller discussion of the history of the ice caps from the LIA to the present (including the area estimates from ASTER through 2016) within the broader context of the studies pointed out above by the reviewer. Section 3 was renamed (Updated History, 1959-2016). The first bullet of the discussion now includes a comparison with the study of Wolken et al. (2008): “To place these findings in a broader context, for the Queen Elizabeth Islands as a whole, trim lines based on high-resolution satellite imagery point to a 37% reduction in perennial snow and ice extent between the LIA maximum extent and the year 1960. Over the lower lying central and western islands, a complete removal of perennial snow and ice occurred by 1960 (Wolken et al., 2008)”. The second bullet highlights that the period of reduced mass loss and occasional mass gains from the1960s through at least part of the 1970s is seen across the Canadian Arctic: “From the 1960s through part of the 1970s, the ice caps may have experienced a period of reduced loss or occasional growth (1971/1972, 1982/1983) in response to cooling. This basic pattern likely holds for Canadian Arctic glaciers and ice caps as a whole (Bradley and Miller, 1972; Hattersley-Smith and Serson, 1973; Ommanney, 1977; Bradley and England, 1978; Braun et al., 2004; Sharp et al., 2014)”.

The third bullet introduces the persistent subsequent mass losses:

“Since then, apart from occasional years such as 1982/1983, annual mass balances of the four ice caps have been persistently negative (Braun et al., 2004). This is in turn consistent with the broader pattern of reductions in mass and area of Arctic glaciers and ice caps (Dowdeswell et al., 1997; Dyurgerov and Meier, 1997; Arendt et al., 2002; Koerner, 2005; Sharp et al., 2011, 2014; Fisher et al., 2012; Sharp et al., 2014; Mortimer et al., 2016). It is also consistent with a negative mass balance of the Greenland Ice Sheet since at least the 1990s (Shepard et al., 2012)”. This set the stage for the next two (entirely new) paragraphs which discuss specific results from other studies:

“Mass balance summaries for four monitored glaciers and ice caps in the Canadian Arctic (Devon Ice Cap, Meighan Ice Cap, Melville South Ice Cap and the White glacier) are provided as part of the American Meteorological Society State of the Climate reports. As assessed over the period 1980 through 2010, all four have had negative average annual mass balances, ranging from -0.15 m w.e. for the Devon Ice Cap to -0.29 w.e. for the Melville South Ice Cap (AMS, 2016). Cumulative changes in regional total stored water for the period 2003 through 2015 based on gravimetric data from the GRACE mission (Gravity Recovery and Climate Experiment) are qualitatively consistent with these mass balance measurements (AMS, 2016). Based on ice core data, Fisher et al. (2012) document rapid acceleration of ice cap melt rates of over the last few decades across the entire Canadian Arctic; the large reductions in area of the Hazen Plateau ice caps, in particular the lower-elevation St. Patrick Bay ice caps, is consistent with this finding. However, reflecting variable climate conditions, annual balances are also quite variable. For example, for the 2013/2014 balance year (the most recent data available), the White Glacier had a strongly negative balance (-0.42 m w.e.) while the small Meighan Ice Cap actually gained mass (+0.06) (AMS, 2016). Sharp et al. (2014) show that while the larger ice bodies in the Canadian Arctic have seen the larges losses in mass, the smaller masses have lost a larger proportion on their areas. This is also consistent with the behavior of the Hazen Plateau ice caps. Below we examine variability in climate conditions over the Hazen Plateau and links to mass balance and area changes".

Later on, in Section 3.2, Associated Climate Conditions, when speaking of the temperature time series, we note that: "The time series of decadal mean summer temperatures at the 700 hPa level for the major glaciated regions of the Canadian Arctic presented by Sharp et al. (2011) based on the NCEP/NCAR reanalysis (their Figure 9.3) is broadly consistent with the pattern shown in Figure 5". The State of the Climate published by the American Meteorological Society that the reviewer recommended also provide some useful insight into the 2012/2103 mass balance year, now discussed in the last paragraph of Section 3.2, in which we call a new figure (Figure 6) showing the summer 825 hPa temperature anomaly pattern:

"Regarding the summer of 2013, the obvious exception to the pattern of recent warm years, the ASTER data and daily images from the Moderate Resolution Imaging Spectroradiometer (MODIS) show extensive cloud cover through the summer, making it difficult to determine whether the snow cover ever entirely cleared off the plateau. It is likely, however, that the 2012/2013 balance year was positive for the Hazen Plateau ice caps - the Devon Ice Cap, Meighan Ice Cap and the White Glacier all gained mass. Only the Melville South Ice Cap, lying well to the west, had a negative balance (AMS, 2014). Consistent with this view, Figure 6 shows that summer (J,J,A) averaged 850 hPa temperature anomalies over the Queen Elizabeth Islands from the NCEP/NCAR reanalysis were about 2oC below the 1981-2010 baseline in the area centered over Axel Heiberg and Ellesmere islands. This reflects the influence of an unusually deep circumpolar vortex at the 500 hPa level centered just south of the Pole along about 90oW longitude. By sharp contrast, the notable area reduction of the St. Patrick Bay ice caps between August 2014 and 2015 aligns with the very warm summer of 2015, essentially tied with 1957 as the highest in the record. From Figure 7, July 2015 temperatures at the 850 hPa level from the NCEP/NCAR reanalysis were 3-4oC above the 1981-2010 baseline over most of northeastern Ellesmere Island. Mass balance estimates for monitored glaciers in the Queen Elizabeth Islands for the 2014/2015 season that would provide context were not available us at the time that this paper came to press".

Comment:

Note that Figure 6 and 7 are presented at a scale that shows conditions over all of the Queen Elizabeth Islands instead of focusing (as the original Figure 6 did) just on Ellesmere Island. The paper is however quite readable (good for presentation quality) although I do suggest below quite a number of detailed edits that would make it more readable.

Response:

We thank the reviewer for these suggested edits and additions.

Comments and Responses:

Specific Points (keyed by line number):

71-74: Specify uncertainties associated with the ice cap area estimates - important to know how large these are relative to the observed changes

Text has been added: “We estimate that these area estimates are accurate to within 5%”.

77: what is the range of surface elevations covered by this transect and how does it compare with the total elevation range of the ice cap?

Additional text has been added to the paragraph: “The range in elevation along this transect was about 60 m, which compares to a range for the entire ice cap of about 160 m.”

85-86: this statement seems like unnecessary speculation, given that the comparison is with the behaviour of a single studied ice cap.

The sentence has been cut.

91: Why assume the 1982 melt season ended by the end of August ? Evidence for this claim? Climate data?

It is of course possible that more melt occurred, although all visible melt had stopped by the time that the field camp had been evacuated and the daily maximum air temperature drops rapidly in late August. However, given that more melt may have occurred, the estimate mass balance of -0.14 w.e. is likely a minimum estimate. The text has been revised to note this. Reviewer 2 also pointed this out.

92-94: an annual mean MB value for a given time interval might be more useful than a period mean and, if there is a stake line, it would be useful to say something about how the annual balance varies with elevation.

The elevation range of the ice cap is quite small and as such, based on the first author’s field notes, no variation in the mass balance with elevation was apparent.

96: decreased in area (rather than shrunk in area)

Corrected.

103: Is -0.49 the annual value or a period mean? Not clear.

It is the total over the period. The text has been amended to: Based on these sparse data, Bradley and Serreze (1987) estimated that over the period 1976-1983, the Simmons ice cap experienced a total mass loss of at least -0.49 meters water equivalent.

104: inferred by Hattersley-Smith. . ...

Corrected.

106-107: Treats temperature and mass balance as interchangeable terms - not justified, so talk about temperature as that is what the data relate to (or present a quantitative relationship that justifies inferring MB from T

This was poor wording on our part. The paragraph now reads: "However, the summer of 1983 was fairly cool and the snow never completely melted off the surrounding tundra. The 1982/1983 annual mass balance for the larger St. Patrick Bay ice cap was estimated at +0.14 m water equivalent, and given their higher elevation, it is reasonable to assume that the 1982/1983 balance of the Simmons and Murray ice caps was also positive".

109: 1982/83 balance of the Simmons. . ...

Corrected.

116-117: annual balances of both ice caps were negative in all years, ranging from. . ..
Corrected.

120: The larger and smaller ..of their 1959 areas respectively, while the

Corrected.

Murray...had shrunk to 70%......their 1957 areas

Corrected.

123: inserted allowed us to make a minimum estimate (-1.10 m w.e.) of the mass loss. . .

Corrected.

125-128: given the measurement approach, I think some assessment of the associated errors is warranted.

Text has been added to the paragraph: “This is based on the mean remaining depth of stake insertion into the ice in 1983 and an assumed ice density of 900 kg m (Braun et al., 2004)”.

129:. . .. . .studies, and the results from. . ...

Corrected.

131: maximum, and likely to have formed

It seems better as “. . ...but rather likely formed. . .”

133: in the first couple. . ..

Corrected.

134-135: On the basis of a mapped lichen tramline, Braun et al. (2004) speculate that

Corrected.

135-138: Here the authors should make reference to Wolken’s study (The Holocene) of lichen trimlines in the QEI; I’d also like to see a tabulation of all the available surface mass balance measurements and the time periods they represent.

The section has been modified as follows: “Braun et al. (2004) speculate on the basis of a mapped lichen trim line that the Murray ice cap may have attained a maximum LIA extent of about 9.6 km2, over twice the mapped 1959 area of 4.35 km2. Similar trim lines were observed around the other three ice caps and although not mapped in detail, strongly point to much more extensive ice cover during the LIA. To place these findings in a broader context, for the Queen Elizabeth Islands as a whole, trim lines based on high-resolution satellite imagery point to a 37% reduction in perennial snow and ice extent between the LIA maximum extent and the year 1960. Over the lower-lying central and western islands, a complete removal of perennial snow and ice occurred by 1960 (Wolken et al., 2008)".

A new table (Table 1) has been added that summarizes all available direct mass balance estimates of the ice cap. Note that the similar table of Braun et al. (2004) includes some additional estimates for other year based on indirect approached.

143: List all the known positive balance years so we can see how many there have been

Done.

147: Note there are GRACE mass balance time series for the QEI (see the Arctic section of successive annual BAMS "State of the Climate" reports) and for the Russian Arctic, Svalbard, and Alaska, so you could make broader scale Arctic comparisons with your data time series. We now include mention of the GRACE results in the revised Section 3.1.

152: areas (in km2) from all. . .

Corrected.

157: of the Murray

Corrected.

162: 2016, the Murray. . .. . ..in 1959. By sharp contrast, ...only 0.15 km2

Corrected.

168: reductions in. . ...area are striking

Corrected.

170: is shown in Figure 3, based on outlines from 1959, 2001, and 2016.

Corrected.

177: Note that none of these studies discuss glacier area changes, and you don't reference the one that does (paper in the GLIMS book)

We now include more references, which include studies of both mass and area changes. The sentence has been amended: "This is in turn consistent with the broader pattern of reductions in mass and area of Arctic glaciers. . ...."

197: is it meaningful to make comparisons with pan-Arctic means given the scale of this study?

We clearly state that we are making an assumption that the inferred LIA conditions over the Hazen Plateau from the study of Kaufman et al. (2011), are at least broadly similar to those for the Arctic as a whole. It is not clear what more can be done here to obtain an optimal local estimate.

200-203: Sharp et al (2011) provide evidence that would support this assumption (i.e. that 850 hPa and surface air temperatures show similar patterns)

The text has amended to point this out.

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-201, 2016.

Printer-friendly version

Discussion paper