

Interactive Comment on “The first complete glacier inventory for the whole of Greenland”, by P. Rastner et al., *The Cryosphere Discussions*, 6, 2399-2436 (2012):

J. Graham Cogley, August 2012

General Comments

The title of this paper is self-explanatory and accurate. The authors have applied semi-automated methods for the identification of glacier ice to a large number of satellite images covering the periphery of Greenland. The image-processing and other analytical methods, including manual correction of the preliminary automated results and checks on accuracy, are described in detail. Most of the images date from 1999–2002, so that the composite view of the ice is nearly a “snapshot”. The resulting glacier-complex outlines are matched to a digital elevation model, with which the complexes are subdivided into glaciers along drainage divides and the resulting glaciers are assigned topographic attributes.

To tackle the practical problem of distinguishing between the ice sheet and the peripheral glaciers, the authors define three “connectivity levels” for the latter, ranging from “physically separate” to “difficult to distinguish”. They recommend treating the difficult-to-distinguish glaciers as part of the ice sheet, a working compromise that will probably satisfy most needs. No matter how the peripheral glaciers are classified, they turn out to be considerably more extensive than as estimated in earlier studies based on incomplete information.

The number of minor stylistic corrections needed is rather large, and there is a moderate amount of repetition that needs to be addressed. Nevertheless the text is clear for the most part. The work has evidently been done competently, and the importance of the contribution is obvious: for the first time we have a complete accounting of the ice cover of Greenland at the level of single glaciers. The ice sheet has yet to be subdivided, but the peripheral glaciers can now be studied in much more detail than has been possible hitherto. There is a wealth of important information in the results of this study, ranging from an accurate and only mildly diachronous estimate of total ice-covered area to a map of median glacier elevations that can serve as a very good representation of the equilibrium-line altitude. Projections of the glaciers’ evolution under 21st-century climatic forcing can also be expected to become far more reliable. In summary, it is important that this work be published.

Substantive Comments

P2400

L2 I would change “important” to “essential”.

L6 “local glaciers and icecaps (GIC)”: The authors’ terminology is frequently confusing. First, an acronym could be avoided if the paper followed IPCC usage and defined “glaciers” to mean “glaciers and ice caps”. Second, “GIC”, “glacier” and “glacier entity” are used inconsistently; for example it does not make sense to speak of “subdividing GICs into glaciers”. A consistent terminology is offered by the *Glossary of Glacier Mass Balance and Related Terms*: a “glacier complex” is a collection of contiguous glaciers. The authors are engaged in mapping *glacier complexes* from imagery and subdividing them into their constituent *glaciers*, and I suggest using these terms throughout. “glacier entity” is especially undesirable, because it is used as if it meant sometimes one and sometimes the other of the two terms I am suggesting.

P2402

L11-12 Dyurgerov and Meier (2005) give 76,200 km², citing Dowdeswell and Hambrey 2002, *Islands of the Arctic* (which I have not seen).

P2404

L9 There is no supplement as such. Call it an Appendix.

P2406

L13 The centre coordinates would be more useful information than just “Greenland”.

L26 This is not very clear. Is the “15 m buffer” really only 15 m wide, or should the text say “±15 m”? If the former, saying “adding a buffer of width 15 m to the exteriors of all ...”. The point should also be made that the ±3% error applies only to glacier complexes. Within complexes, single-glacier errors will differ by an amount dependent on the length

of ice margin, the length of the glacier's divides, and a "divide error", presumably unknown, that will be perfectly anti-correlated with the corresponding errors of the glacier's neighbours. (One glacier's loss is the other glacier's gain.)

P2407

L7

The two sets of connectivity rules are described fairly clearly, and they serve the intended purpose. The subjectivity of the procedure is also acknowledged appropriately. But one very obvious feature is not given any attention: the procedure assumes the existence of an object called the "Greenland Ice Sheet", *of known outline*. The rules cannot be applied until the ice-sheet outline is drawn. You have to identify every ice-sheet divide and assign it to either CL1 or CL2, following which you can apply the topographic heritage rule and then finish by assigning all the CL0s. It should be noted that different results will be obtained depending on whether the heritage rule is applied first to the CL1 or the CL2 glaciers.

The broader significance of these points should be emphasized. For example the inventory is indeed complete for the whole of Greenland, *including* the ice sheet, which differs from the other glacier complexes only in that it is the only one that has not been considered for subdivision. Although it would be large ($>10^6$ points?) and diachronous (constructed from many scenes differing in date), the ice-sheet polygon could be included in the inventory just like all the other polygons.

P2409

L3

Why "zonal"? It confuses the reader by suggesting elevation zones, which do not seem to be relevant. A "zone" seems to be what most people refer to as a "mask". In fact, the sentence could profitably be ended at "aspect)".

P2410

L4-5

In view of the embarrassing mistake documented by Kargel et al. (2012), it would be worthwhile to be more precise about the areas of the ice sheet and of all ice in Greenland. For example, can an uncertainty be attached to either number by multiplying 15 m by the length of all glacier-complex perimeters (plus the margins of the ice sheet)?

L11

Change "included" to "excluded from the ice sheet". State briefly why King Christian IV Glacier has been assigned to the ice sheet rather than CL2. Perhaps the ice-sheet divide is too indistinct, or simply does not exist. The extent of ice in question (11,000 km² for King Christian IV and almost as much again for its neighbours that would inherit CL2 connectivity) is large.

P2411

L14

Clarify "very reduced influence of the MAAT". I do not know what is being referred to.

P2412

L6-12

This is an accurate statement of the truth but it is too informal to appear in print and needs to be dressed up. I would say "... with the ice sheet. The divides as derived from flowshed analysis are obtained objectively, but need human The interpretation offered here is a working compromise that will help to reduce the risk of double-counting by different groups (Paul, 2011). When ...".

L14

"all datasets are digitally available": vector "polylines", as opposed to polygons, are needed for the purpose discussed here, and it is very unusual to make them available.

P2413

L6

Cogley (2012) is not in the References.

L18

I do not understand "the total area covered by upscaling the size class distribution", in which "covered" and "class" seem to be redundant and "upscaling" is obscure. But I see no need for a discussion here of volume-area scaling, if that is what is aimed at.

L23-25

I do not understand this. Standard inventory practice is to assign a special aspect code for "radial flow" to ice caps. The "certain preference ..." clause does not make sense.

P2414

L13-15

Why, if it too is accurate, will a different DEM result in different divides and attributes?

P2415

- L1 Explain why relative uncertainty is inversely proportional to area (“increases, because the ratio of area to length of perimeter becomes large.”).
- P2421
Table 1 This table should be rearranged to resemble Table A2, with columns for area and number and rows for CL0, CL1, CL2, ice sheet (“CL3”), ice sheet plus CL2, and the whole island. The numbers in the ice-sheet row are confusing. For example it is not helpful to subtract CL0 area from total area and call it “ice sheet”.

Stylistic Comments

- P2400
- L4 “past, future and potential total”.
- L4 “Although Greenland is heavily ..., a complete inventory of its glaciers is not available.”.
- L7 “results of such an inventory, compiled from ...”.
- L10 “parameter” is misused throughout the paper and should be replaced everywhere by “attribute” or “property”. A parameter is a coefficient of a model that is a constant in any one instance of the model but that may vary from instance to instance. For example there are two parameters, a and b , in the model $y = a + b x$.
- L13 Delete “specific”.
- L14 “The glaciers larger than 0.05 km² number ~20,300 (of ...”
- L14 Insert a tilde before “900”. The number is 907 in Table A2.
- L16 “the strongly-connected CL2 glaciers”.
- L17 “smaller than”.
- L19 “is located”.
- L21 “on the distance”.
- L26 Change the first comma to “and”. Change “could potentially” to “is expected to”.
- P2401
- L2 Change “precise” to “accurate”.
- L3-4 “The periphery of the Greenland Ice Sheet is one of the regions”.
- L6-7 “differently defined separation”.
- L6-8 “problem”. It is not a “situation”.
- L16-17 “occur not just in coastal regions away from the ice sheet, but also on mountain ridges within and adjacent to ...” (although I am not sure that an ice sheet can contain a mountain ridge, because by definition it obscures the topography on which it sits).
- L18 “requirements of”.
- L21-22 “This is required, for instance, to avoid double counting of contributions to”.
- L23 Do not hyphenate “ice masks”.
- L24 “have been inventoried”.
- L29 “The two currently available Greenland-wide vector datasets of the total ice-covered area are <the DCW and the GIMP>, but they do not separate the local glaciers from the ice sheet or from each other.”
- P2402
- L4 “similarly comprehensive”.
- L5 “held”.
- L6 “The data sets vary”.
- L8 “For lack of complete inventory data”.
- L9 “assessed by a range”.
- L13 Delete “also”.
- L14 “has also received only limited attention so far.”.
- L15 “has required either the application of rough ...”.
- L18 “the new and complete inventory presented here”.
- L21 A comma before “secondly” as well as after. Change “allow” to “make possible”.
- P2403
- L3 “the whole of Greenland”. The ~9 other instances of “entire Greenland” (some in figure captions) should also be altered.

L8 “into four”.

L10 “... subpolar. The island acts ... as a large store of freshwater.”

L22 “in the northeastern interior”.

L26 Insert “to” before “extended”.

P2404

L7-8 “focussing on Landsat 7 ... dating from before the failure of the scan line corrector (SLC) in 2003”.

L11 “several scenes from after the SLC failure that had much less snow cover ...”.

L12 “We also made some use of Landsat TM ...”.

L17 “To address”. “of Landsat data”.

L21-22 “as ice shelves and some ... had to be removed”.

L22 “Iskappe”. But why not “Ice Cap”?

L23 “does not consider all debris-covered”. “excludes”.

L24 Do not hyphenate “northernmost” (make it one word).

L25 “of the GIMP dataset”.

L26 Delete “overall”.

P2405

L3-4 “extraction only provides ... and therefore does not work”.

L5 “coarser” rather than “lower”.

L7 “of locally”.

L12 Delete “overall”.

L13 “into three steps”.

L14 “and from each other”. “(c) intersection of the glacier-complex outlines with the drainage divides, and a”. “glacier-specific”.

L20 “threshold ratio”.

L21 “as ice when Band 3/Band 5 exceeded 1.6”.

L25 “inventory. They were manually”.

P2406

L6 “polygons within which”.

L7 “polygons” rather than “regions”.

L18 Hyphenate “round-robin”.

L21 “the two methods”.

L22 “that results for debris-covered ice were strongly variable, with differences greater than”.

L24 “As the locations of manually-digitized outlines were found by Paul et al. (2012) to vary by”.

L25 “outlines derived here”.

L27 “uncertainty for glacier areas”.

L2407

L2 “We derived drainage divides to separate the glacier complexes into glaciers in a two-step”.

L3-4 Change “watershed” to “flowshed” throughout the text.

L4 “a modified verion of an approach”.

L11 Delete “also”. “different observing and modelling communities,”.

L17-18 “confluent flow”.

L25 “are”, not “were”. This sentence illustrates well the confusion brought about by “GIC” and “entities”.

L26 “starts”.

L2408

L7 “A further set of rules to separate the glacier complexes consistently is:”

L13-14 “the fewest glaciers should be created”.

L16 That rule III is also subjective should be acknowledged.

L17-18 Comma after “ice caps”. “... glaciers. Only one of the ice caps is subdivided,”.

- L25 Use “drainage basins” sparingly. The text will be clearer if it only speaks of intersecting a glacier complex with a basin (two polygons), or a glacier outline with a drainage *divide* (two lines)
- P2409
- L10-15 I would turn the sentence around: “Although the standard deviations . . . , we found that the differences On that basis we deemed the GIMP DEM acceptable for use over the whole of Greenland.”
- L19-20 “in the east, and some smaller regions, have CL2 connectivity.”
- P2410
- L2 “CL2 glaciers add . . . for a total”.
- L15 “and Greenland as a whole”.
- L17 “but together they account for only”.
- L20 “larger than”.
- L21 “by sector”.
- L25 “second largest glacier class”: what does this mean? The second largest of the size classes?
- L26 “sectors”. Also at L29.
- L27 “The size distribution by aspect sector for CL0 and CL1 glaciers is concentrated”. “NW to SE”: you cannot have a “cluster” ranging over half of the compass.
- P2411
- L1 “slight” rather than “small”.
- L2 “by aspect”.
- L4 “are depicted”.
- L6-7 “sectors, with remarkably different maxima”.
- L8-9 “to the predominance of ice caps, and maybe”.
- L10 “creates”.
- L11 “sectors”.
- L12 “homogeneous”. “extents” rather than “values”.
- L13 You can say “points to” or “hints at”, but not “hints to”. This should be checked elsewhere in the text.
- L16 “and the area-elevation distribution is thus the same as that of Greenland as a whole.”.
- L22 Change “increasingly higher” to “increasing”. Delete “When”.
- L24 Delete “of a region”.
- L26 “inferred”, not “derived”.
- P2412
- L3 “rules for subdividing glacier complexes into glaciers are certainly matters for discussion.”.
- L4 “Schon Weidick” does not translate as “Already Weidick”. You have to say something like “Some time ago Weidick”.
- L17 “domes”.
- P2413
- L3 “are obtained from”.
- L7-8 This repeats material from P2402. In general sections 5 and 6 could be condensed by avoiding a number of repetitions like this one.
- L13 “also that the volume of the”.
- L17 “by size class”. “to distributions reported for other”.
- L18 “allow of obtaining”.
- L19 “there is some regional variability”.
- L20 “may not have been accurately representative of other regions.”.
- L22 “is a rough estimate that depends on the algorithm for creating divides”.
- L23 “the aspect distribution presented here”.
- L28 “trend has also been found”.
- P2414

- L1 Paul et al. (2011) is not in the References, and Paul (2011) does not seem a likely alternative.
- L7 “networks only measure accumulation, not precipitation”.
- L9 Delete “also”. Change “applied” to “on which it relies”.
- L12 “accurate”, not “precise”.
- L13 “DEMs”.
- L15-17 “with the ASTER GDEM II”. Delete “for both”. Delete “still present”. “GDEM II”.
- L17 “So until”.
- L22 “similar to that found in other”.
- P2415
- L3 “considerable”.
- L4 “delineated accurately because at the latitude of Greenland low solar”.
- L8 “The impact ... is”.
- L12 “mosaicking”. “with much less snow cover than in the SLC-on scenes”.
- L14 Change “Conclusions” to “Summary”, and try to reduce repetition.
- L15 Delete “satellite derived”.
- L20 “50% greater”. “estimated”, not “assumed”.
- L21 Change “yields” to “we obtain”.
- L22 “are”, not “were”.
- L23-25 “This ... communities.”: delete this sentence.
- L2416
- L1 “Because the locations ... depend ... rules for subdividing glacier complexes, differences from other assessments can be expected.”.
- L6 “smaller than”.
- L7 “reduce the uncertainty due to seasonal”.
- L9-11 “distributions ... are similar to those found in other regions. The greatest number of local glaciers is found in the east sector and the smallest in the west.” “different topography of the two regions”.
- L12 “a dependence of glacier area on aspect”. “sectors”.
- L13 “showed”.
- L17 “determining”.
- L26-27 “Raymond LeBris”. Delete “us”.
- P2422
- Table 2 “The GGI ... dataset of this study includes”.
- P2427
- Figure 1 Change “Geikei” to Geikie” in the map.
- P2428
- Figure 2 I suggest changing “Glacier Outlines” to “Glacier-complex Outlines”; “Glacier Basins” to “Drainage Basins”; and “Glacier Entities” to “Glaciers”. In the Results box, capitalize “Area”.
- P2429
- Figure 3 Replace the second sentence of the caption with “Glaciers contiguous with the ice sheet are assigned a connectivity first. Their unassigned contiguous neighbours then inherit the same connectivity, CL1 or CL2, and finally detached glaciers are assigned to CL0.”
- P2434
- Figure 8 Mention the lowest and highest observed median elevations in the caption. If possible, increase the size of the coloured dots of Flade Isblink and the very large glaciers on the Geikie Plateau.