

TCD Review:

Characterization of Canadian High Arctic glacier surface albedo from MODIS C6 data, 2001-2016

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General Comments:

The manuscript presents an important effort in understanding Canadian High Arctic glacier albedo and surface temperature. Change in Queen Elizabeth Islands (QEI) glacier surface albedo is presented from the combined Aqua and Terra MODIS Collection 6 albedo product and change in glacier surface temperature is presented from Terra MODIS Collection 5 Land Surface Temperature and Emissivity product. The temporal period of the analyses include QEI summer months (June, July, August) from 2001-2016. Albedo and land surface temperature changes are evaluated and presented as monthly and seasonal averages as well as spatial patterns. Satellite analysis is compared with reanalysis data, some complementary observation data and studies published to date.

Major Considerations:

As written, the manuscript can be difficult to follow. The Data and Methods section provides appropriate content and detail. However, the manuscript may benefit from reorganization of content in the Introduction, Results, and Discussion sections. Content in the Discussion section could be moved to the beginning of the manuscript, with the option to provide a 'Background' section. Supporting details of complementary observations (e.g. snowfall, temperature) introduced in the Discussion might be better placed earlier in the manuscript, near results (see line by line suggestions below). In addition, there are grammatical errors and smaller ordering inconsistencies throughout the manuscript that deter from readability. Careful editing and attention to detail is needed in revising and ensuring the success of this manuscript.

In the data and methods section (Page 4, line 122) MOD10A1 data was mentioned "to be a reasonable representation of the true surface albedo". Does this refer to analysis conducted by the authors for this manuscript or to Box et al., 2017? Please clarify. If MOD10A1 data was not inspected by the authors for this manuscript, why not? Additionally, is there a reason the authors have focused on Terra data? The manuscript may be strengthened by analysis of MODIS Aqua MYD10A1 and Terra MOD10A1 data. As stated, the MCD43A3 data represents data acquired from both Terra and Aqua sensors. Calibration challenges which have primarily impacted Terra data may be teased apart by analysis of Aqua MYD10A1 data, Terra MOD10A1 data, and combined sensor MCD43A3 data.

Section 2.2 discusses MODIS LST data. Why was Collection 5 MOD11A2 data used? (Page 5, lines 155-157) Communication with the MODIS data distributor, LP DAAC, revealed that MOD11A2 and MYD11A2 Collection 6 data have been available since mid-2015. Additionally, with the discussion of the

Terra sensor degradation, it seems shortsighted to use Terra data only. Why was Terra data used? Was Aqua data used (i.e. MYD11A2)? If not, why not? Recommendation to add MYD11A2 data analysis.

Reorganization of content is advised toward readability. There are several cases where content is difficult to follow. Example, Results Section, 3.1 Suggestion to add sentences clarifying and further detailing results. As written, parts of the section are terse and non-intuitive. Lines 196-197 Why does Table 1 2001-2016 average differ from manuscript stated average (i.e. Table 1 states 0.599, manuscript states 0.550)? For example, readers may appreciate a sentence stating that in addition to the JJA averages, monthly mean albedo was also calculated (Table 2). Include references to Tables, methods as appropriate.

Similarly, in the Discussion section, it is stated that “delayed snowfall onset and limited melt in August were inferred from the GRACE mass change record”. However, earlier in the manuscript, speculative statements are made on snowfall patterns, implying there is no quantitative data nor analyses to site for QEI. Use of a specific snowfall proxy data (i.e. GRACE, reanalysis) or other observational datasets would be more quantitative than speculative remarks currently in the Results and Discussions sections. Two specific areas of speculation are: (1) Results Section 3.1, line 203, ‘may indicate early onset of snowfall that fall’ and (2) Results Section 3.2, lines 290-292 snowfall patterns may be changing in QEI). Quantified data based statements are preferred over speculation where possible.

Recommendation for the authors to clearly state the additional QEI LST analysis provided in this manuscript as compared to Mortimer et al., 2016. (See some line by line comments below.) I recommend considering the role of the QEI LST analysis in this manuscript.

Specific, Minor Comments:

Was the Randolph Glacier Inventory used to delineate QEI glacier analysis areas? If so, please state clearly where appropriate (i.e. manuscript text, figure captions) and cite.

Page 2, line 38 – What is meant by ‘accelerated release’? Suggestion to reword, clarify intent.

Page 2, lines 40-42 – The authors are correct to state fresh snow would raise surface albedo. Suggestion to include QEI precipitation data quantifying the suggestion, or reference precipitation studies.

Page 2, line 49 – Suggestion to clarify for readers the source of the temperature analysis used in referenced studies.

Page 3, lines 89-91 – Suggestion to edit sentences. As written, one could glean that it is difficult to discriminate between surface snow and ice vs cloud spectral visible-thermal infrared response. This is not always difficult to do spectrally. If the authors intend to discuss cloud remote sensing only, please clarify this. A more appropriate reference than Hall 2008a, may be Hall et al., 2002, MODIS snow-cover products, Remote Sensing of Environment, 83, 181-194.

Page 4, line 98 – Delete ‘some of’.

Page 4, line 102 – Lyapustin et al. was not the first to report on Terra’s band degradation. Recommendation to additionally read and cite early / appropriate work, e.g. Xiong et al., 2001, Degradation of MODIS optics and its reflective solar bands calibration, doi: 10.1117/12.450646

Xiong and Barnes, 2006, An overview of MODIS radiometric calibration and characterization, doi: 10.1007/s00376-006-0008-3

Sun et al., 2014 Time-dependent response versus scan angle for MODIS reflective solar bands, IEEE TGRS, doi: 10.1109/TGRS.2013.2271448

Page 4, paragraph 3. Suggestion for authors to reread literature on MODIS sensor calibration, degradation and capabilities. Line 110, more correct to state that C6 did improve radiance measurements from launch to ~2013. It remains to be assessed how accurate and reliable MODIS C6 data will be moving forward from C6 implementation (~2013 to present). Recommendation to check the MODIS Characterization Support Team literature <https://mcst.gsfc.nasa.gov/publications?f%5Btype%5D=102> . For lines 113-114, it is not that the sensor is capable of identifying trends greater than 0.01, so much as +/- 0.01 is the limit of MODIS sensor accuracy and precision. The paragraph could be rewritten to be more informative and clear regarding MODIS sensor design and capabilities.

Page 5, line 129 – Suggestion to move citation to correct location in the sentence, i.e. Schaaf and Wang 2015 reference should immediately follow MCD43 product mention.

Page 5, line 141 – Awkward as written, suggestion to reword to clarify further use of BSA term e.g. ‘henceforth BSA refers to the black sky albedo MODIS shortwave broadband data.’

Page 5, lines 151-152 – The authors seem to generalize in that “uncertainties in the MOD11A2 LSTs arise mainly from cloud contamination”. Suggestion to reread relevant literature and present accurately. Does the sentence refer to over snow only?

Page 6, line 159 – Is there a reference from precipitation records/data in QEI? i.e. what station, record or data is 400 mm/yr derived from?

Page 7, line 195 – Suggestion to include MCD43A3 for clarity and completeness.

Page 9, line 272 – Note that it is not only the calibration accuracy that limits the capability to measure trends, but also the sensor design. Please add reference to sensor capabilities (e.g. Justice et al., 1998, doi: 10.1109/36.701075 and/or similar on MODIS instrument design and post-launch capabilities, see <https://mcst.gsfc.nasa.gov/publications?f%5Btype%5D=102>).

Page 12, lines 365-366, Suggestion to reword sentence, avoiding use of “positive (negative)” words side by side.

Page 12, lines 376-377 It is stated that “delayed snowfall onset and limited melt in August were inferred from the GRACE mass change record”. Did the authors process GRACE data, or does this reference a study? If it references a study, please include the citation. If the authors processed GRACE data, please include mention of in Data and Methods.

Page 13, lines 407-409 Example of content that may be better placed in the beginning of the manuscript.

Page 15, lines 465-466 Example of sentence where it is difficult to assess what is new in this manuscript vs. Mortimer et al., 2016.

Figure 1 caption – Do the authors intend to reference Moderate Resolution Imaging Spectroradiometer instead of “Moderate Resolution Spectroradiometer”?

Figure 1 image – In some formats, it is difficult to differentiate the thematic colors used in the figure. Consider if there may be other colors to use. For reader friendliness, it may also help to move the legend and increase the font size of the legend text.

Also, consider adding a label to the 8 regions. This may help readers in interpretation of Supplemental Table S2.

Figure 4 – Figure text, misspelled word ‘anomaly’ in two locations, please correct.

Figure 5 – Why there is no data (white in figure) for the period 2001-2016 in some locations of QEI ice?

Figure S7 – Example of important, interesting QEI LST content for the authors to consider moving from the supplemental material to the main manuscript.