Interactive comment on “Icelandic Snow Cover Characteristics derived from a gap-filled MODIS Daily Snow Cover Product” by Andri Gunnarsson et al.

Anonymous Referee #1 Received and published: 28 March 2019

Response to Anonymous Reviewer #1

Author response is in red

Reviewer #1 General comments:

This study presents a complete characterization of snow cover characteristics in Iceland based on a remote sensing product. The authors present the methods used to obtain a gap-filled dataset of snow cover based on a Moderate resolution Imaging Spectroradiometer (Modis), as well as the validation of this product with other satellite data and in-situ observations. Although the context of the novel methods and satellite products is explained well, the study could be better placed in the context of the importance of snow cover studies under climate change. After a successful validation the dataset, the authors analyse the characteristics of snow cover extent and duration over the whole of Iceland. Despite the limitations of satellite products in polar latitudes due to polar darkness and clouds, a thorough monthly analysis of snow cover from year 2000 to 2018 is presented. A trend analysis for such a short period is also done. I do not see a major issue on that, since the aim of the paper is not to present a trend analysis and the conclusions are not weakened, but some parts of it require a clarification or a rephrasing of the text. A data product of this spatio-temporal characteristics over a highly snow dependent region such as Iceland did not exist before and is therefore an advance for snow and hydrological studies. The methods could be further used in other snow dependent regions where the satellite products have coverage, and therefore publication of this article would promote scientific progress. In addition, the article falls well in the scope of the journal since such a complete snow cover product might be of interest for catchment and water cycle studies over Iceland and for operational use as e.g. in the prediction of hydropower generation based on snowmelt. The text follows a logical story and in general is well written, with all sections explained thoroughly in detail. I suggest accepting the paper for publication after improving some minor issues of the trend analysis, as well as the presentation of some results and figures and the writing of some parts of the text, as I detail below.

Author response #1:

First, we would like to thank Anonymous Reviewer #1 for very useful comments and a general positive feedback about our submitted manuscript.

Specific comments (minor issues):

Reviewer #1 Comment #1

Introduction:

In the first paragraph of the introduction, more references could be used to place the reader in the context of snow cover studies based on satellite products (https://doi.org/10.5194/tc-5-219-2011, https://doi.org/10.1029/2012GL053387 , https://doi.org/10.1175/2010JCLI3644.1) and the importance that these have because continental perspectives on snow cover changes due to climate change, based

on insitu observations, are only starting to become available and data is scarce (especially over Iceland) https://doi.org/10.1029/2018GL079799

Author response #1:

More discussion and details will be added to a modified manuscript in the context of snow cover studies based on satellite products as suggested above. This has also been pointed out by reviewer #2.

Reviewer #1 Comment #2

Data and Methods:

In both sections the order of "in-situ data" "Modis data" and "Landsat-Sentinel data" should be the same, it is now different and confuses the reader. I suggest 3.1 to be "in-situ" data, 3.2 to be "Modis" and 3.3 "Sentinel".

Author response #2:

We agree and will revise the text accordingly. This has also been pointed out by reviewer #2.

Reviewer #1 Comment #3

The methods section is quite technical and therefore could highly benefit from a schematic Figure representing the types of data and the types of processing of the data, in the form of a "flowchart". This would help the reader follow better the whole methods process.

Author response #3:

We have a draft of a figure showing in detail how the classification process is undertaken and another one where the MODIS data flow is shown. Based on those we will add a figure that shows the main processing steps of the data structure including temporal merging, daily aggregation and cap filling procedures.

Reviewer #1 Comment #4

Results:

Table 1:

Can you please provide an explanation or at least hypothesis on why agreement is lower when observations show snow than when they show no snow? For instance, if satellite products were to confuse a cloud with snow, that would lead to a lower agreement when observations show no snow than when they show snow. The difference is big so there should be some reason as for instance that snow is not deep enough for the satellite product to be detected?

Author response #4:

Possible explanation for a lower agreement could be the mismatch of pixel boundary extent compared to the manned observation "extent". This relates to many of the in situ snow cover sites are located within or close to cities and small municipals where buildings, roads and other civil structures could influence the NDSI value from MODIS towards classifying the pixel not snow covered while the manned observation would classify the site as snow covered. The lower agreement could also be attributed towards the different observation methods as the manually observed snow cover is based on a manned observation from the ground while MODIS provides an areal average of the NDSI value within each pixel.

Reviewer #1 Comment #5

Figure 4:

The display with a different colour for every month gives no additional information since nothing can be seen from the colours (except for a few clusters). I suggest that a correlation between landsat and modis is computed for every month and then presented in a table. This would potentially identify in which months MODIS performs best or worse and would give a more complete validation.

Author response #5:

The authors feel that the figure shows the correlation nicely but agree that the coloring of month do not add any information. Colors will be removed.

Reviewer #1 Comment #6

Some statements about Figure 10 and 11 on trend analysis should be treated with more care. Page 15, lines 25-30: "In February and March [. . .] some areas where snow cover extent recedes over the period"; The statement is too strong, since looking at Figure 10 right column Feb-Mar, trends over almost the whole of Iceland are in the middle column) is highly insignificant.

A similar statement is written for Oct-Nov, with trends that are generally smaller than 1.5%, and when considering the whole year (Feb-Nov). I suggest decreasing the strength of the statements or showing the trends differently, for instance computing the trend divided by standard deviation (in days, not percentage). This would should on the map to what extent these changes are significant and might support the significant increasing trend obtained for June when computing the snow covered fraction (Figure 11).

Authors response #6:

The authors agree that this needs to be clarified. Suggested change is as follows:

Sentence is:

"Figure 10 (third column) shows trends in snow cover within each period. In February and March the average trend is close to zero with some areas (red) where snow cover extent recedes over the period. For April/May, June/July and August/September the average trend for each period is positive, indicating that the snow cover extent was spanning a longer time, i.e. snow cover was extending further into the spring and summer months. For early winter, October and November, the average trend was negative

meaning that snow cover was on average less, especially in the east and north. Further details of this are shown in Figure 11 where monthly mean snow cover extent was calculated for all years and the data were fitted linearly."

Authors modification #6:

"Figure 10 (third column) shows trends in snow cover within each period. In February and March the average trend is close to zero **(insignificant for all areas).** For April/May, June/July and August/September the average trend for each period is positive, indicating that the snow cover extent was spanning a longer time, i.e. snow cover was extending further into the spring and summer months. For early winter, October and November, the average trend was **slightly** negative meaning that snow cover was on average less, especially in the east and **north in the order of 0.4 to 3 days**. Further details of this are shown in Figure 11 where monthly mean snow cover extent was calculated for all years and the data were fitted linearly."

Reviewer #1 Comment #7

Regarding these increasing trends for May, June and July, the significance for such a short period could be explained by the 3 abnormal years in 2013, 2014 and 2015. Although this is stated in the results, I suggest that this is mentioned in the conclusion. Moreover, the conclusion should indicate that an increase is only observed in June or spring, as it is well indicated in the abstract (Page 19, line 1): "The changes over time (trend) analysed for the 18 years showed a slight increase in average snow cover in spring, probably driven by 3 abnormally cold years in 2013, 2014 and 2015. This aligns . . ."

Authors response #7:

The authors agree that this needs to be clarified. We suggest modifying the sentence (P19, Line 1) in the Conclusion to:

Authors modification #7:

"The changes over time (trend) analysed for the 18 years showed a slight increase in average snow cover in spring, likely driven by the three cold Springs in 2013, 2014 and 2015 and extended liquid phase precipitation in the fall for the same years.

Reviewer #1 Comment #8

- P.5 L-19: Please explain what tile h17v02 is and where it comes from

Authors response #8:

We suggest expanding the last sentence in 2.2 Modis Snow Cover data to:

"Data from NSIDC are gridded using in the MODIS Sinusoidal Tile Grid system which covers approximately an area of 1200 km by 1200 km with a nominal 500 m spatial resolution. Tile h17v02 was used in this project as it covers all the central highlands in Iceland and leaves out only a small portion of the west Snæfellsnes Peninsula and the Westfjords (dataset citation)."

Reviewer #1 Comment #9

- P.7 L-4: Abbreviation MCDAT appears here for the first time but it is not explained, please provide the full name for it.

Authors response #9:

We will add the following:

MCDAT (MODIS Combined Data for Aqua and Terra)

Reviewer #1 Comment #10

- P.7 L-7: What is the best observation of the day? Can there be two best? What happens then?

Authors response #10:

This is an internal processing step at NSIDC so processing details are sparse but the main criteria is based on that each observation represents the best sensor view of surface in the cell based on solar elevation, distance from nadir, and cell coverage. Iceland having a high latitude has multiple daily overpasses by both satellites that are merged. We find it very unlikely that two observations can have the same quality (be best) as solar zentih angle will always be different in one data set even if the cloud cover (cell coverage) and distance from nadir would be the same. No change to the text in the manuscript is needed.

Reviewer #1 Comment #11

- P.8 L-20: Are the numbers correct? 213.011 matches out of 585.800 is less than 50% accuracy.

Authors response #11:

This is correct. The context is that out of 585.800 available manned in situ observations there are 213.011 instances where a daily match can be found from MODIS, that is this relates to cloud cover over the in situ observation site. This aligns well with the high average cloud cover over Iceland, where only 30-40% of the time a Modis observations is available for a manned observation.

Reviewer #1 Comment #12

- P.8 L-25: “at the bottom” - Figure 3: Please change the colour scale to a continuous one, otherwise it is difficult to read the map.

Authors response #12:

We will update the color scale as suggested for Figure 3.

Reviewer #1 Comment #13

- I suggest merging Figures 5 and 6.

Authors response #13:

The authors feel that it is better to have these figures as two.

Reviewer #1 Comment #14

- P.12 L-9: While the text indicates that December and January are not available, Figure 8 shows 11 months of data. How is that possible?

Authors response #14:

This is a mistake in axis settings. It is correct the December and most of January are omitted for the study due to polar darkness. We will correct the axis.

Reviewer #1 Comment #15

- P.15 L-29: This result contrasts with other studies showing a shortening of melt season and earlier onsets https://doi.org/10.1175/2010JCLI3644.1

Authors response #15:

It is generally true in the Northern Hemisphere that the shortening of the melt season and earlier onset of melt is observed. However, there are abnormalities for local areas. Our results suggest that this is true for Iceland and are supported by other recent similar work. (https://doi.org/10.1016/j.jag.2019.04.003)

Reviewer #1 Technical corrections/clarifications:

- p.2 L-8: What is the order of the references? It is not alphabetical and not old to new.

This will be corrected

- P.2 L-21: Remove extra brackets in (Fig 1,2)

This will be corrected

- P.4 L-29: I suggest changing “main objective” for “aim”, since after this sentence a first and second objective are presented.

This will be corrected

- P.5 L-14: Join the two references.

This will be corrected

- Figure 9: Please increase figure size if possible.

This can be done in typesetting of the manuscript