Response to Reviewer #2

Interactive Comment on "Assessing spatio-temporal variability and trends (2000-2013) of modelled and measured Greenland ice sheet albedo"

This paper is an important contribution to understanding mass loss from the Greenland ice sheet as albedo is one of the central variables in this process. In this paper, several different products of Greenland ice sheet albedo are compared, including satellite, regional climate model and in situ data. The insights provided in this paper are highly valuable as many scientists use these datasets and models. The methods and data interpretations are sound. Most of my comments are about presentation of the material and organizing the manuscript.

Major comments 1. Follow the Introduction-Methods-Results-Discussion manuscript structure, which many readers expect of this kind of paper by making the following corrections:
 a. Add new sections to the methods section that describe your comparison methodology and analysis of trends. For example, describe the method you used to calculate trends (linear regression or non-parametric methods?).

Section 2.5, "Methods of Analysis" has been created. Some of the material from the original sections describing comparison methods has been moved here, and a new section (2.5.5) discusses statistical techniques.

 b. Several new analyses and their methods are introduced in the discussion section. Consider moving the presentation of the analysis shown in Figure 12-14 to the result section, and explain the methodology of these two analyses in the methods section.

The structure of the manuscript has been altered as suggested by reviewers 1 and 2. The discussion of MAR v3.2 vs. 2.0 (originally section 4.2.3) has been moved to section 3.4. The new material originally presented in section 4.2.1 has been moved to section 3.1. Various statements with regard to methodology have been removed in the discussion section and are now included in the new methods section.

2. Paper can be rewritten to be more concise. For example, figure caption text sometimes appears in several figures or both in the caption and the text. It may be sufficient to only write it once. Furthermore, you do not have to explain what the figure shows in the text (e.g. sentences starting with "In Fig. X, we show" since this is made clear in the figure caption. I have pointed out some but not all occurrences below.

The suggested changes have been made wherever possible, and have improved the flow of the manuscript.

3. Could the correlation in Figure 7 be close to zero in the accumulation zone because the standard deviation is close to zero? If the data has no variation, no correlation is expected. If so, the correlation analysis is not suitable to describe the similarity between the datasets in this region.

Yes, we intended to imply this in the statement:
"Within the accumulation area, correlation between MAR and MODIS products is generally poor ($r^2 < 0.2$) and not significant at the 95% confidence level. Again, in this region, variability is smaller than the assumed uncertainty for MCD43A3."

To be clearer, the final paragraph of section 3.2 now begins with:

"For areas south of 70°N and in the ablation area north of 70°N, the two MODIS products are highly correlated (for MCD43A3 16 day periods, $r^2 > 0.5$), but in the accumulation area north of 70°N this correlation decreases (Fig. 8a). Poor correlation in this area is likely a result of the low standard deviation of albedo which falls within the uncertainty range for MODIS."

And ends with:
"Again, in the accumulation area, it is difficult to draw any conclusions regarding correlation, as the variability in albedo is smaller than the assumed uncertainty for the MODIS products."

Minor comments

P3734. L26. Consider rewriting this sentence. There is not 'direct' relationship between temperature and melt. It is the surface energy balance that drivers surface melting.
The sentence has been changed to read: "Increased melt over Greenland has been associated with both changes in temperature and an amplifying ice-albedo feedback: increased melting and bare ice exposure reduce surface albedo, thereby increasing the amount of absorbed solar radiation and, in turn, further amplifying melting (Box et al., 2012; Tedesco et al., 2011)."

P3736. L1-4. Be more specific about what products you are using in your comparison and provide more insights to your methods to give a roadmap of the paper here. State the number and exact MODIS products used, as well as the two AWS datasets, also clarify that you are using MAR 2.0 and 3.2 as RCM. Mention that you have regridded data and calculated averages over the same time interval to make intercomparison possible. Here you can also state the study period and what part of the ice sheet you are considering. Finally, explain that you are also investigating potential errors due to differences in albedo spectral range, MAR albedo scheme, etc etc. You can remove lines 5-8 since it follows the standard structure for a scientific paper.
Further details have been added here following the above suggestions. The sentences referring to the paper structure have been removed.

P3736. L4. The reference to Fettweis does not seem necessary unless you explain why he used MAR 2.0 over 3.2 in his 2013 papers.
(We assume the reviewer was referring to P3737). The reference has been removed there.

P3736. L18. Rewrite. You are using both MAR 3.2 and 2.0 in this paper.
The sentence and portions of the subsequent paragraph have been revised to indicate that we focus primarily on MAR v3.2, but also consider MAR v2.0 outputs.

P3737. L10. Remove "some". Presumably "all" ice edge stations with less than 100% MAR ice covered where analyzed in this way. If not, you need to list which stations you applied this method too and explain why only 'some' ice edge station were analyzed this way.

This sentence has been removed from this section. We now provide more specific details in section 2.5.3. Indeed, we use data from the MAR "ice-covered" sector in the comparison in *all* cases where a station falls within a MAR grid box with less than 100% ice cover.

P3737. L25. Repetitive

The sentence has been revised to read:
"Albedo has been defined in MAR for three spectral intervals:"

P3738. L7. Consider substituting "bands" with "ranges".

We have chosen to use the word "interval", which is also used at a later point in the text.

P3744. L1-8. This belongs in the method section. You can be more assertive, there is little doubt that surface albedo in JJA is most important for SMB.

The methods material here has been moved to section 2.5.5. "Is likely to have the largest impact on SMB" has been changed to "has the largest impact on SMB".

P3744. L8-10. Consider remove sentences like this to make article more concise. This information is given in the figure and table captions. I propose you go straight to your results and refer to figures in parenthesis.

The sentences have been removed here, and wherever possible the suggested revisions have been made.

P3744. L13. Add a reference to Figure 2 at the end of this sentence.

The section now begins with this sentence, and it refers to Figure 2.

P3744. L20. Instead of "compared to Fig 3a" spell out what product differences are shown in Fig 3a.

The sentence has been revised as noted in the response to the next comment.

P3744. L20. I disagree with your interpretation of Figure 3. It is difficult to see if the spatial variability in 3a is less than in 3b and 3c. While 3a does not have the strong positive anomalies in Fig 3b and 3c, it appears to have the strongest negative anomalies.

The intent was to point out differences in patterns of spatial variability rather than the magnitude of spatial variations in albedo. The sentence now reads:
"The pattern of differences between MAR v3.2 and the two satellite products (Fig. 3b and c) appears to vary with both elevation and latitude, while the difference between the two satellite products varies primarily with latitude (Fig. 3a).

P3745. L18-24. Consider removing to make the paper more concise. This is "methods" and I believe it is already explained there.

These sentences have been removed and some of the information has been moved to the Methods section.

P3746. L6-7. This sentence is also in the figure text. It only needs to appear once.
The sentence has now been removed.

P3746. L23-25. Rewrite. Replace standard deviation with spatial variability. The figure "indicate" something about spatial variability.
The sentence has been revised to read:
"Within the low elevation ablation area of the ice sheet, both MAR and the MODIS products exhibit a relatively high standard deviation for the 2000-2013 period (0.07 on average for 16 day periods; Fig. 7, Table 3)."

P3747. L15. Specify what kind of correlation (e.g. Pearson or Spearman). Spearman correlation may be warranted given that the data does not have a normal distribution.
We use Pearson's correlation, which is now specified in the Methods section (2.5.5). We calculated the Spearman correlation as well, but found a relatively small effect on correlation in the ablation area, where the data are least likely to be normally distributed, but a more substantial effect where the data are not normally distributed. We feel that calculating Pearson's correlation is sufficient for our purposes and provides a better indicator of correlation in the accumulation area.

P3747. L18. Be careful how you refer to R2 throughout the paper. R2 is the coefficient of determination, while R is the correlation coefficient.
"Correlation" or "correlation coefficient" has been changed to "coefficient of determination" when referring to what is plotted in Fig. 7 (now Fig. 8).

P3748. L13-17: Move to methods. Make a new section to explain your methodology to analyze trends.
We assume the reviewer is referring to P3749. The sentence has been moved to Section 2.2.5 where we discuss methodology for computing trends.

P3749. L7-8. This sentence is unnecessary. It is clear from the figure captions.
The sentence has been removed.

P3756. L4-5. Clarify if this is a recommendation or something that will be implemented.
This has been implemented in the latest version of MAR. This has been stated and further discussion has been added.

P3757. L1-2. Why not show this analysis in this paper. Rewrite, remove or add the analysis.
Since the analysis did not reveal statistically significant differences, we feel that it is unnecessary to include a figure here.   The paragraph has been shortened to a single sentence:
"We also investigated the possibility that the smaller spectral interval of GC-Net data influences trends by comparing MCD43A3 visible vs. shortwave albedo trends, but did not find the trends to be significantly different from each other."

Table 2 and 3 captions: Consider removing "Summary of" or use "Summary statistics"
"Summary of" has been removed.

Figure 1: Clarify that the black stippled line in the inset represents elevation contours (not ELA as in the larger figure)
The black stippled lines in the inset have been changed to solid lines to be consistent with the larger figure.

Figure 3: Explain what the 'hatched' areas represent.
Statement added: "MAR grid boxes where the difference is not statistically significant at the 95% confidence level are marked with a grey 'x'."

Figure 4: Graph can be improved so that different data can be distinguished more clearly. For example, give each line a unique color and show poor quality by using spilled lines instead of symbols. Consider removing the good or all quality data from the figure since it is not discussed in the text and it clutters the figure.
Lines on the figures have been made thicker and the symbols have been made smaller so that the lines are now more clearly visible. The good vs. all quality data are mentioned in the discussion section 4.2.1. Therefore we prefer to keep all data on the figure.

Figure 5: Figure 4b and 5 are extremely similar. Consider removing Figure 4b from the manuscript.
We would prefer to keep Figure 4b in the manuscript, as Figure 5 is useful for comparing station data to data for all MAR grid boxes in the accumulation area, but Figure 4b provides a summary of icesheet-wide albedo as a function of latitude.   Figure 4b is also mentioned in the discussion section in the context of MODIS data quality.

Figure 7: Rewrite. R2 is the coefficient of determination, and R is the correlation coefficient.
"Correlation coefficient" has been changed to "coefficient of determination" on the figure and in the text. (This is now Figure 8).

Figure 10: Correct "95% level" to "95% confidence level".
Corrected. (This is now Figure 13).

Figure 11: Here the y axis labels denotes unitless with "(-)". This is different from how albedo was presented in previous figures (the unitless only mentioned in the caption). Either way is fine, however, be consistent throughout the paper. Consider using the same axis interval for all graphs to make it easier to compare the trends between the three plots.
 "(-)" has been changed to "(unitless)" on the y-axis. The same axis interval (0.45) was originally used on all graphs but the axis on Fig. 14c is offset by 0.1 as the average ablation zone albedo is lower. A note has been added to the caption stating: "Note that the y-axis interval is the same for all graphs, but is shifted by 0.1 for (c)." (This is now Figure 14)

Figure 13: Shouldn't the density distributions for MAR 2.0 in panel a and c be the same? The same goes for MAR 3.2 in panels b and d.
An error in the code used to create this figure was discovered that results in a different bin size for histograms for the comparison with MOD10A1 data. This has been corrected so that the bin size for all histograms is 0.0099. The distributions are still slightly different, because only coincident MODIS and MAR data are used for each plot, and missing values from MOD10A1 do

not necessarily correspond to missing values from MCD43A3. Statistics for the data (such as those presented in Table 5) remain unchanged. (This is now Figure 11).

Figure 14: Consider adding a sentence that explain that the average SMB is negative, which means a positive bias is "less" negative and results in "less" mass loss.
A sentence has been added stating this:
"Note that in the ablation area, where net SMB is negative (Fig. 1), a positive SMB bias indicates a smaller amount of average mass loss." (This is now Figure 12).