

Response to Reviewer 1:

Interactive comment on “Assessing spatio-temporal variability and trends (2000-2013) of modelled and measured Greenland ice sheet albedo” by P. M. Alexander et al.

Anonymous Referee #1

The following is a review of “Assessing spatio-temporal variability and trends (2000-2013) of modelled and measured Greenland ice sheet albedo” by P. M. Alexander, M. Tedesco, X. Fettweis, R. S. W. van de Wal, C. J. P. P. Smeets, and M. R. van den Broeke

This manuscript is a brief communication, investigating how modeled albedo compares with satellite-based and in situ observations. The authors focus on comparison between the spatial and temporal variability of albedo on the Greenland Ice Sheet surface during the summertime. The modeled albedo is a product of the latest version of the MAR Regional Climate Model (v3.2). For a comparison, the authors include results from a previous model version, which implements a different albedo scheme (v2.0). The study finds agreement amongst all products that low-elevation albedo has decreased over the last decade. They also find that, in this area, MAR exhibits a positive bias. In the accumulation area, they find that two different MODIS products show a decrease in surface albedo. However, this trend is neither reproduced in the model nor present in the in situ observations, suggesting that MODIS instrument degradation may play an increasingly significant role in these types of analyses.

As the authors point out, this is the first time an assessment of this kind has been presented with respect to surface albedo over Greenland Ice Sheet. The analysis presented here is thorough and well thought-out. Clearly, a good deal of work was put into trying to put model results on equal footing with different types of observations, so that they could be compared in this manner. Results are kindly presented in a variety of ways, in order to highlight product differences and to aid in the discussion. In addition, this study advances the scientific community’s understanding of the biases that exists in regional climate models and at the same time, brings to light those that may be present in remote sensing products. Therefore, I recommend this paper for publication in The Cryosphere.

A few general comments for the authors’ consideration:

- Title: The title is awkward, especially with placement of the years. Perhaps placing the years at the end might help this? (“Assessing spatio-temporal variability and trends of modeled and measured Greenland Ice Sheet albedo (2000-2013)”?)

The title has been changed to: “Assessing spatio-temporal variability and trends in modeled and measured Greenland ice sheet albedo (2000-2013)”

-Abstract: An additional final sentence about the significance of these results or repercussions they would have on the community would make the abstract stronger. Also, it is not necessary to define ablation and accumulation in the abstract.

As suggested, a final sentence has been added to the abstract highlighting the significance of the study’s results. The definitions of ablation and accumulation areas have been removed.

- A number of times, model results are referred to as ‘data’. Please refrain from this terminology when discussing ECMWF and MAR output fields.

We have replaced all references to MAR or ECMWF “data” with appropriate terms such as “outputs” or “results”.

- Consider using the terms accumulation and ablation ‘area’ instead of zone, since you are usually assessing the entire area as a whole.

All references to “ablation zone” or “accumulation zone” have been changed to “ablation area” or “accumulation area.” (Also suggested by Reviewer #3)

- You also may want to consider introducing results of the MAR3.2 and MAR2.0 comparisons earlier in the paper. If this was done in the results, it would make for a clearer and more direct discussion in section 4.2.3.

The results of the MAR3.2 vs. MAR 2.0 comparisons (Section 4.2.3) have now been moved to the results section (Section 3.4). Section 4.2.2 has been modified to incorporate discussion of the results in Section 3.4. The figures and tables have been rearranged appropriately.

- Some simple titles, or indicators on the figures would be helpful for fast reference. It would save the reader from having to constantly refer to the captions for a reminder of what is being compared.

Additional titles have been added to Figure 2, Figure 3, Figure 6 (Now Figure 7), Figure 7 (Now Figure 8), Figure 10 (Now Figure 13), Figure 11 (Now Figure 14), and Figure 14 (Now Figure 12). We feel the others do not need additional titles as they already have axis labels.

- I found myself getting confused about the values of min and max dry snow and bare ice albedo values for the different models. A simple table of these values would be very helpful for reference and maybe make the albedo ranges clearer to the reader. Then you would not have to always insert the values into the text. (For example, ‘maximum bare ice albedo’ is equal to .55 but bare ice albedo can range up to 0.6 – section 4.2.3).

Table 1 now provides the range of values for snow, ice and firn for MAR v3.2 and v2.0 and values have been removed from the text in some instances. The statement that bare ice albedo can “range up to 0.6” was incorrect. This has been revised to read “range up to 0.55”.

Below, I offer some more specific comments/suggestions:

Page 3735, line 23-29: Please consider rephrasing. This sentence is awkward.

The sentence has been removed and replaced with the following two sentences:

“Nevertheless, given their relatively high temporal and spatial resolution, these products are useful for evaluating albedo derived from regional climate models (RCMS). RCMS are an important tool for estimating both current and future changes in the GrIS SMB (Box and Rinke, 2002; Box et al., 2006; Ettema et al., 2009; Fettweis et al., 2007, 2011; Rae et al., 2012, Tedesco and Fettweis, 2012), and the surface albedo schemes employed by these models

have a substantial impact on their simulation of the SMB (Rae et al., 2012; van Angelen et al., 2012; Lefebvre et al., 2005; Franco et al., 2012).”

Page 3736, line 23: Reference for ERA? (Uppala, 2005)

References to Uppala et al. (2005) for ERA-40 and Dee et al. (2011) for ERA-Interim have been added in the text and the reference list.

Page 3737, line 23: The use of ‘vice versa’ here is not clear.

The relationship between these grain properties and optical diameter is in fact somewhat complex, and unnecessary to include here. We have simply revised the text to read “MAR snow albedo (α) depends on the optical diameter of snow grains (d), which is in turn a function of other snow grain properties, such as grain size, sphericity and dendricity.” Readers who are interested in further details can refer to the references provided.

Section 2.3: It would be nice to specify that MODIS is available 2000-2013, since state the years in the MAR and the in situ sections.

The range of dates for the MODIS products is now provided in section 2.3.

Page 3746, line 1: Please be more specific that the term ‘close to’.

The sentence has been removed. We have added a more specific mention of biases at K-Transect and GC-Net sites.

Page 3748, line 2: Typo, ‘products’

The typo has been corrected.

Page 3751, line 1: Reference for snow metamorphism?

The paper Wiscombe and Warren (1980), which was already provided in the reference list, has now been cited in section 4.1.

Page 3751, line 11: This statement suggests that these papers showed that albedo trends are driven by atmospheric circulation changes. It is my understanding they connect the melt to circulation change (but not actually the albedo trends to the circulation). Please review this sentence for clarity.

Yes, this was the intended meaning of the sentence, but we agree that the meaning was ambiguous. The sentence has been split into two:

“...captured by models (Fettweis et al., 2011; Ettema et al., 2009) and in situ observations (van de Wal et al., 2012). Increased melting has been linked to warmer regional atmospheric air temperatures, associated with atmospheric circulation changes (Fettweis et al., 2013a; Häkkinen et al., 2014).”

Page 3759, line 11: Perhaps ‘confirm’ instead of ‘prove’?

The reviewer must have been referring to Page 3757, line 11. “Prove” has been changed to “confirm” as suggested.