Response to Reviewer #3 (Jason Box)

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.

Jason E Box (Referee)

Summary It is nice to see a rigorous study of Greenland albedo. The paper is of significance for findings that include 1.) "difference in mean albedo of up to 0.08 between the two remote sensing products north of 70 N 2.) a disagreement in the trend magnitude between the two MODIS albedo products for the accumulation area, and 3.) likely positive bias in MAR simulated bare-ice albedo.

major critique
The use of relatively coarse 25 km horizontal resolution when the MODIS data are available at a much higher resolution raises the question of resolving the ablation area and fine structures [e.g. Wieltjes and Oerlemans 2010] observed in the ablation area.

The MODIS data are aggregated to the MAR 25 km grid in order to conduct comparisons with MAR. For analyses involving in situ stations, MODIS data at the original resolution of the MODIS products (463x463m) have been used. The focus of this study is not to reveal all details of spatial variability in Greenland Ice sheet albedo, but rather to use multiple datasets and model results to capture variability at the scales examined. We now indicate the importance of capturing albedo variations at a higher spatial resolution in the concluding paragraph.

page 3734 lines 20-21 "not confirmed by either the model or in situ observations" untrue an accumulation area albedo decline is documented in in situ observations. See Box et al. (2012) for MODIS see section 4.2 Albedo trend verification 4th paragraph.

As noted in section 4.2.3, it is not clear why there is a discrepancy between the results presented here and those of Box et al. (2012). We have added a sentence to the abstract to indicate that the findings contradict with a previous study.

"Nevertheless, satellite products show a decline in JJA albedo of -0.03 to -0.04 per decade for regions within the accumulation area that is not confirmed by either the model or in situ observations. These findings appear to contradict a previous study that found an agreement between accumulation area in situ and MODIS trends during individual months."

page 3735 lines 22-23 incoporate critique of Wang and Zender using Schaaf et al. (2011)

This critique has been discussed in section 4.2.1. We feel that the argument that in general, high solar zenith angles lead to less accurate albedo measurements is not affected by this critique, but have removed the reference to Wang and Zender (2002) in this portion of the paper as it is not essential to include here.

page 3745 line 1 While MAR abackground albedo has not yet been mentioned in the article, I suspect that "large positive bias in MAR albedo" are because a background albedo that 'reflects' [pun intended] MAR not incorporating impurities from, for example, outcropping dust [Wientjes et al. 2010]?

We agree that the fact that MAR does not account for impurities in the ablation area contributes to the bias in this region. The "dark zone" is discussed in section 4.2.2, and we have expanded this discussion somewhat in the revised manuscript.

It is unfortunate PROMICE.org weather station data were not used. Presumably the authors saw Cryolist emails from Dirk van As on the data availability. PROMICE AWS have [usually] more accurate radiometers than GC-Net radiometers. PROMICE AWS compliment GC-Net by being concentrated in the ablation area where the albedo change signal is the largest.

We were aware of this dataset, but were not aware of its availability online when data analysis for this study was conducted. While the use of additional measurements would certainly improve this study, we do not feel that the measurements would substantially alter the findings presented here. Given limited time and resources we cannot include the data but are open to utilizing it in the future.

page 3746 lines 10-11 The hypothesis: "MOD10A1 may also be positively biased north of 70 N" could be tested using PROMICE.org data from the KPC_U and KPC_L station data.

These stations are placed along the edges of the ice sheet. To assess variability with latitude at local stations (Fig. 5) we have focused on stations within the MAR-defined accumulation area, with a record of at least 9 years. We have deliberately avoided ablation area stations for this analysis as albedo there is subject to high variability and is influenced by processes such as melting, bare ice and dust exposure. While the data from these stations might provide some indication as to the validity of the hypothesis, we don't think they would provide definitive conclusions regarding a positive bias in MOD10A1.

page 3750 section 4.1 1st paragraph seems unnecessary and speculative. Regarding "datasets", it would be useful to make more distinction between simulation from MAR and observational datasets. The framing should perhaps be how well or not MAR performs relative to this and that observational dataset.

We do not think this discussion is speculative, as it is consistent with previous literature. Some additional references have been added.

We now refer to MAR model "outputs" or "results" rather than "data."

section 4.2.1 Variation of albedo with latitude. it's hard to conclude anything with confidence because all datasets (perhaps not MAR in this case) will have some solar and viewing geometry dependent bias.

We have noted this in section 4.2.1:

"Part of the reasons for discrepancies in the latitudinal dependence of albedo may be associated with biases resulting from viewing geometry or sun angle, which vary with latitude, making it difficult to draw conclusions from the various observational datasets as to 'true' variations in albedo with latitude."

minor critique

throughout, consider replacing + "zone" with "area" to adopt a standard suggested by Dorothy Hall, one that is more accurate since, in my view, a zone is a latitude interval.
This change has been made throughout the manuscript.

"mean" with "average", the former is more jargon than the latter.
We prefer to use the term "mean" as it refers to the arithmetic mean, which we have calculated here, while the term "average" seems more ambiguous.

page 3734 line 3 delete "crucial", unneeded
The word "crucial" has been removed.

page 3735 3 replace "accelerating" with "amplified"
"Accelerating" has been replaced with "amplify".
11 "increasing" instead of "record"
The suggested change has been made.

page 3736 lines 4-5 "To our knowledge, this is the first-time that a multi-tool integrated assessment of albedo over Greenland is presented." why is this important? Each publishable study does several things for the first time, no? This sentence should be removed.
We think that it is important to state why this study is different from previous evaluations, so that the reader is aware of the contribution of this study to the existing literature.

Page 3741 midday instead of noontime
"noontime" has been replaced with "midday".

page 3744 line 13 not just "meltwater and bare ice" but dust and algae. There are several papers of the topic such as: Bøggild, C.E., Brandt, R.E., Brown, K. J., and Warren, S.G.: The ablation zone in Northeast Greenland: ice types, albedos and impurities, J. Glaciol., 56, 101-113, 2010. Wienjes, I.G.M. and Oerlemans, J.: An explanation for the dark region in the western melt zone of the Greenland ice sheet, The Cryosphere, 4, 261-268, doi:10.5194/tc-4-261-2010, 2010. Wientjes, I.G.M., R.S.w. van de Wal, G.J. Reichart, A. Sluijs and J. Oerlemans, 2011. Dust from the dark region in the western ablation zone of the Greenland ice sheet. The Cryosphere, 5, 589-601. Doi: 10.5194/tc-5-589-2011
We have also referred to the presence of impurities and have cited these references.

page 3746 17-18 remove "Therefore," unneeded
The sentence has now been removed.

page 3746 17-18 “of the four datasets examined, only MCD43A3 appears to exhibit a decrease with latitude above 70°N. Only 3 datasets have a substantial latitude range. PROMICE.org data would be a 4th dataset.
The sentence has now been removed. Regarding PROMICE.org data, see responses at the start of the second page of this document.

Ablation vs. high latitudes.

first page 16 “indicates” instead of “points to”
“point to” has been changed to “indicate”

page 3749 “undergoes” or “exhibits” instead of “experiences” which is a sentient phenomenon
“Experiences” has been changed to “undergoes”.

page3753 6 “above 0.84” comes from Konzelmann, T. and Omura, A.:, J. Glaciol., 41, 490-502, 1995. where albedo was measured to a Swiss standard, i.e., extremely carefully and therefore their maximum values for fresh snow are credible.
The reference has been cited here and included in the reference list.

Page 3756 21 remove “in”
“in ablation zone areas” has been changed to “within the ablation area” .

page 3758 16 refer also to Stroeve et al. (2013)
The reference has been added.

ps. I am sorry for taking so long to make the review after accepting the assignment.
No problem, thanks for taking the time to review it!