The Cryosphere Discuss., 6, C1385–C1390, 2012
www.the-cryosphere-discuss.net/6/C1385/2012/

The Cryosphere Discussions

Interactive comment on "Sensitivity of Greenland Ice Sheet surface mass balance to surface albedo parameterization: a study with a regional climate model" *by* J. H. van Angelen et al.

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Received and published: 3 September 2012

AC: We are grateful to the reviewer for providing detailed and constructive comments, which helped to improve the paper. All issues raised are addressed below.

This paper presents a study with the RACMO2 model of how various factors influence Greenland ice sheet surface albedo, and the impact on ice sheet surface mass balance. Before publication it is recommended that the authors consider major and minor concerns listed below.

Major comments 1) Despite many references to the "old" RACMO albedo scheme, there are no comparisons with this scheme. Instead, the authors compare a series of

simulations with the settings used for an Antarctic study. It would be more logical and interesting to compare the new simulations with the old simulations using the density dependent albedo.

AC: We have added the results for the density dependent RACMO2 simulation to Figure 6. Next to that, Figure 3 shows albedo using the density dependent albedo scheme to illustrate the issue with two low albedos (fast melting of the snow) close to the equilibrium line. In the result section the improvement for net shortwave radiation is discussed compared to the previous scheme as well as the averaged albedo.

Furthermore, the naming convention of the simulations can be improved. For example, "CONTROL" is typically used to name baseline simulations, but here it is the name used for the simulations with the most changes.

AC: The naming for CONTROL is chosen because in future studies the simulation using these settings will be used as standard simulation, i.e. control. The naming of the other experiments is chosen to express in one word what is changed in that specific experiment.

2) Consider formulating hypotheses about expected results from the model simulations shown table 1. This will help the reader understand what to expect from this paper and why the different model simulations parameterizations were chosen.

AC: The section where the different model simulations are described is extended to describe what the influence of a certain parameter is on the albedo scheme, and which region of the ice sheet is affected. "Table 1 summarizes the various albedo experiments with RACMO2. The ANT settings are the settings used for the Antarctica integration (Kuipers Munneke et al., 2011; Lenaerts et al., 2012). With every new experiment one parameter is changed. In FSGRAIN the specific surface area of fresh snow is decreased from 80 to 60 m2 kg-1, equivalent to an increase in effective radius of the grain size (re,0) from 41 to 55 μm, leading to a lower albedo for fresh snow. In the previous RACMO2 snow albedo scheme, the maximum amount of liquid water in the snowpack was limited to 2%. In the new snow albedo scheme, this artificial limit is no longer applied, and the amount of liquid water in the snowpack is calculated following Coleou and Lesaffre (1998). In their expression, the maximum amount of liquid water is related to the available pore space in the snowpack and can reach values of up to 13% of the weight of the snowpack (experiment LWMAX). A higher amount of liquid water in the snowpack will stimulate refreezing, and consequently albedo will decrease. Next, in RFGRAIN, the grain size of refrozen snow is increased from 1 to 2 mm, which lowers albedo of refrozen snow. In ICEALB the constant ice albedo is decreased from 0.5 to 0.45. In RSOOT black carbon is added to the snowpack (0.1 ppmv), which reduces snow albedo. In the final simulation (CONTROL), the MODIS based background ice albedo field is used instead of a spatially constant value, which will affect the melt rates in regions where bare ice is present at the surface for part of the year.

3) Discuss the relative merits of AWS and MODIS in providing "ground truth" and explain why these two different albedo products were used for validation.

AC: We added discussion on the two products and the cons and pros for each: "The AWS albedo measurements have the advantage of temporal accuracy, but fail to represent the albedo for larger grid cells. The MODIS albedo data, on the other hand, cover larger areas and consequently better represent the albedo of the entire grid cell, but lack the temporal accuracy (e.g, due to the 16-day compositing (MDC43 data) or 11-day median values (e.g., Box et. al. (2012)"

4) The manuscript lack a discussion section.

AC: A specific discussion section is not present in the manuscript, but throughout the result section discussion and quantification of the results is added. See also the comments on Jason Box' review.

5) Consider revision of Figure 4. It is easy to misinterpret because of the two y-axis scales. At first glance, it appears as if the most amount of black carbon has the least impact on albedo. Instead, I propose the authors either split this figure up into two

panels, or only use one y-axis scale where they show the snow albedo factoring in 0ppv, 0.05ppv, 0.1ppv black carbon concentration etc

AC: We have compared the suggested figure to the figure now in the manuscript. In our view, the figure at present depicts better for what grain size (i.e. snow conditions) the impact of black carbon is largest. So we decided to keep this figure as it is.

6) Clarify the evaluation method. The methods states that evaluation will focus on year 2007 and S9. Yet, Figure 6 shows many years, and Figure 9 shows an average 1991-2010 for several stations.

AC: The evaluation of the albedo parameterization is done for the year 2007, by simulating this specific year several times with different parameter settings. The best settings are chosen for a simulation for the period 1960-2011, based on validation with S9 and the number of melt days from SSM/I retrievals. Results of this simulation are in the end compared to the previous scheme for data from the k-transect.

Minor comments P 1534.L 21. Clarify your evaluation methods. Here the "second" method is mentioned, but there is no clear mentioning of the "first" method.

AC: We addressed this: "As a second evaluation method, next to the AWS data, we use the amount of melting days in the summer of 2007 based on satellite retrievals."

P 1534.L 24. Explain why you regrid to EASE grid

AC: The data is already delivered by NSIDC in EASE grid. So, the re-gridding is done by them, as is stated in the text now.

P 1536. Equation 1: Explain that the terms dau and so on refers to the change in albedo due to these factors.

AC: This explanation is added.

P 1536. L 19: Provide an assessment of RACMO cloud cover simulation if possible underestimated SMB not being related to albedo is incomplete: how about the albedo at S6 (1000m)? Figure 5 show that for year 2007, it is lower than observed. How much of the underestimation can be attributed to this? By how much is the sensible heat flux overestimated at S6 and S9?

AC: This section is changed to: “Between 1000 and 1700 m elevation, the total SMB is still underestimated by 0.5-1.0 m w.e. As a result, a discrepancy between the equilibrium line altitude in RACMO2 (around 1800 m in Figure 10) and the stake measurements of 200 m is present. This offset is probably not related to albedo, since the remaining bias between measured and modeled albedo at station S9 (1500 m) is too small to explain a discrepancy of 0.5 m w.e. Ettema et al. (2010a) demonstrated that the sensible heat flux (SHF) is overestimated by up to 20 W $m{-2}$ at S6 and S9 for the summer months (JJA), equivalent to $\pm$40 cm of ice melt. SHF can thus be regarded as a realistic candidate to explain the offset as seen in Fig. 11, especially because the overestimation of SHF by RACMO2 is not present at station S5. It should also be kept in mind that, especially in the area around the equilibrium line, surface mass balance estimates derived from stake measurements have a large uncertainty, because the density of the melted (superimposed) ice and firn is not accurately known.”.

P 1536. Equation 2: State the unit dimensions of the variables. Explain what d stands for in this context.

AC: corrected

P 1537. Equation 3: Provide context for this equation. Is it an empirically derived equation? If so, what data was used? Also, provide information about unit dimensions.

AC: Added: “The parameterizations for the base albedo and the different corrections are derived using a snow-ice-atmosphere radiative transfer model.”

P 1537. L 19: Clarify if this refer to snow grain diameter or radius? P 1538. L 20-23: Explain why these constraints were used

AC: Added “with a radius between. . .”

P 1538. L 24: What value was used in areas not expected to become snow free. What is meant by "coming years"

AC: Grid points, which do not become snow free, do not need an ice albedo.

P 1539. L 15-17: Explain why you did not use GC-Net station data from the ablation zone or near equilibrium line to evaluate your work? I concur with reviewer Box that conclusion section should not be used to discuss future work.

AC: The study of Ettema et al (2010a) showed that the largest offset for RACMO2 concerning albedo occurred along the western ablation zone (where S9 is located). Therefore we have chosen to focus the tuning of the new albedo scheme on this station. This is added in the text. The discussion on future work is moved to the results section.

Interactive comment on The Cryosphere Discuss., 6, 1531, 2012.