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Climate of the Past Discussions



# *Interactive comment on* "The importance of snow albedo for ice sheet evolution over the last glacial cycle" *by* Matteo Willeit and Andrey Ganopolski

**Anonymous Referee #1**

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Willeit et al. quantify the impact of snow albedo parametrisation (snow aging and dust deposition) for the simulation of the last glacial-interglacial cycle in a model of intermediate complexity. Snow albedo is a crucial parameter for the surface mass balance of the ice sheet and its temporal evolution (over this timescale) is poorly constrained. As such, the study is largely justified. However, in my opinion the manuscript suffers from some important omissions about: study justification/novelty, model description, model validation and methodology discussions (listed below). As it stands the authors mostly show the impact of a higher snow albedo in simulating the last glacial-interglacial cycle.

General comments

- The novelty in this work is not presented in a clear way. The snow albedo is known to be one of a major control on ice sheet surface mass balance and several authors have



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already explicitly tested this in coupled ice sheet – climate simulations (e.g. Calov et al. 2005; Bonelli et al. 2009; Helsen et al. 2017; Fyke et al. 2011). Also, it seems difficult to see clearly the difference between this study and the one of Ganopolski et al. (2010), except for the use of an interactive scheme for dust deposition (which is not validated here). Ganopolski et al. (2010) have already shown the importance of dust in their results (Sec. 5.3, quoting): "Hence, at least in our model, accounting for the additional source of dust related to the glacial erosion is crucial for simulating of a complete termination of the glacial cycle [...]". Given that: i) the conclusions in Willeit et al. (2017) are almost identical to the one of Ganopolski et al. (2010) and; ii) there is no real improvement in the model; I feel like the study needs a stronger justification.

- Methodology. The model has been tuned to reproduce the glacial-interglacial cycles for a specific snow parametrisation. I am thus not surprised that the omission of one process affecting the snow albedo lead to an erroneous ice sheet evolution. Are the authors testing the actual processes (dust/aging) or simply the value of the albedo? Switching between off and on the two processes with the same value for the fresh snow albedo is an unjustified oversimplification. They could have tried to retune the model without the aging and/or dust (considering a perpetual "dirty fresh snow" for example): if they were able to show that it is impossible to get a realistic ice sheet volume evolution in doing so, then they might have claimed that aging/dust are clearly important. In addition, if the real novelty of this work is to use the interactive dust, they should have shown the difference of their model compared to the prescribed dust version of Ganopolski et al. (2010).

- Validation of the scheme: the study could be more convincing if the aging and dust parametrisations were validated against observations or state-of-the-art model simulations. In particular, it could be useful to see if the scheme reproduces the seasonal variations of albedo of the Greenland ice sheet and high latitudes regions. Again, as it stands, the reader is left with the impression that the parametrisations have been chosen (tuned) to reproduce the last glacial-interglacial cycle. As a result it is obvious

that the model will not work if the processes are not included. I would also like to see how well the dust deposition changes over Greenland along the cycle simulated by the model compares to actual dust in Greenland ice cores.

- Model presentation: the albedo computation in the model should be presented in this paper, in particular on how age and dust relate to albedo. The reader has to check the appendix of Calov et al. 2005 to get more information on this. Also, the same is true for the dust from glaciogenic sediments, for which the authors only state that the model accounts for. I also think that more information on the SEMI model could be added (which variables are bilinearly interpolated? Which variables depend on sub-grid topography? Etc.).

Specific comments

P2L1 In fact, algae could be more important than non-algal impurities for bare ice albedo (Musilova et al. 2016; Stibal et al. 2017).

P2L23-24 SEMI does not perform a physically based downscaling of climatological fields. Most of the variables are bilinearly interpolated. The SMB is physically based though.

P2L27-28 Does this include the Antarctic ice sheet?

P3L5 How this is computed? Can you really differentiate between the two types of dust? Please expand on this.

P3L7 On which grid are you looking that? The SICOPOLIS grid or the native atmospheric grid?

P3 Eq.X? Is this calculated on each atmospheric timestep? What is the value of the atmospheric timestep?

P4 Fig 1 The CLIMBER2 albedo presented here is the one tuned to reproduce the glacial interglacial cycles and they are systematically below the values of Dang et al.





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and Gardner and Sharp ( 0.1 difference, except for pure snow where it is very close). This is not surprising that using one of Dang et al. or Gardner and Sharp results in an overestimation of the ice volume.

P4L12 Antarctic kept constant to present-day observations?

P5 Figure 2 Why the surface mass balance is increasing over the Holocene whilst the ice volume remains constant?

P6L19-20 You state in line 8 that the simulated dust deposition is roughly 3000 Tg/yr but later you mention the scaling factor to get 3000 Tg/yr. This is confusing: what is the actual simulated dust deposition before the application of the scaling factor? Using an other scaling factor you could end up with significant study conclusions (maybe for more dust, you might no need the snow aging to reproduce the cycles. . .).

P6 Fig 3 This is only aeolian dust? Do Mahowald and Lambert include the glaciogenic dust as well?

P6 Fig 3 It could be nice to have the extent of the (observed) ice sheets for the two time periods on this plot.

P7L8 The dust effect is larger at the LGM because you have the contribution from the glaciogenic sediments?

P7L13 I do not understand this statement: your ice albedo is 0.4 and your old/dirty snow has an albedo which can be lower than 0.4.

P8 Fig 5 Why there is a corridor of low albedo values between the coastal grid points of the gulf of Alaska and the rest of the Laurentide ice sheet?

P8 Fig 5 Is the depicted albedo only for grid points covered by an ice sheet? If not, please add the extent of the simulated ice sheet in this.

P9 Fig 6 Does the surface mass balance scheme includes any kind of refreezing?

P9 L17-20 [...] “From the experiments presented and for this model formulation” should be added. Again, I am not convinced that you actually test the actual processes. Extrapolating: the use of Dang et al. and Gardner and Sharp does not allow for a realistic cycle neither, does this mean that there is still a missing process like algae?

P10 L1 How this is computed? Can we really distinguish this from the rest of the dust? It could be useful to have a map of this.

P10 L3-4 Is it fair to say that this is a tunable additional source of dust in order to produce a realistic cycle?

P10 L3-4 Your maximum dust over the whole cycle is at about 15k thanks to this glaciogenic dust. It seems important to clearly state where does this come from and why this process only appears at the end of the cycle. A few maps at selected snapshots could be nice for albedo, dust and SMB.

P11 L10-12 “ice is covered by snow most of the year, even in net ablation areas” To melt the ice sheet you need to melt the ice in summer, using the ice albedo. Can you give more explanation on why the ice albedo is not playing in your deglaciation scenario?

P11 L12-16 These experiments are interesting, to my opinion. It would have been nice to see these experiments combined with the omission of snow aging. Increased dust but no aging might produce a realistic cycle? Or combining dust deposition scaling factor with Dang et al. or Gardner and Sharp parametrisation.

General

- What about the sea ice albedo? Do you have a similar scheme that includes dust and aging? If not, why.

- The computed SMB is a function of albedo, but also it depends on the other energy balance terms. In particular, how transparent your clouds are is probably very important for the surface mass balance. Snow albedo is always crucial for the SMB, but you might

not need dust to reproduce the cycle for different parametrisation of clouds.

Technical corrections

P9 Fig 6 The location of the two sites are not indicated by black boxes.

P9 L15 Replace Nord by Northern

P9 L16 && L18 Separately instead of “in isolation”

P11 Fig 9 there is no blue boxes in Fig 5.

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