

Review of Zeitz et al in the cryosphere discussion

Summary

The study presents a new module for the ice flow model PISM, making it possible to include effects of changes in global radiation and albedo, in the model. In order to make a computationally efficient experiments, MAR albedo and global radiation is not used directly but implemented as parametrisations. This model setup is then used to explore the effect of the melt-albedo feedback in PISM. The manuscript covers a description of the method and performed experiments testing the effect of the implemented module and parametrisation on model prescribed ice mass loss.

The originality is that the study presents a new module to calculate melt in PISM. This module is as simple to implement as the pdd melt model, given that albedo and transmissivity is parametrised, but then offers the benefit of being able to add both effects of changing surface reflection, and incoming shortwave radiation. In this way it is possible to model the effect of changing incoming radiation on melt in for example the Eemian interglacial as well as investigating the effect of the melt-albedo feedback in predictive ice sheet models.

The significance of the study is the implementation of a new module in PISM, making it possible to experiment with the melt-albedo feedback as well as orbital parameters in PISM, and that the modelled ice loss is significantly altered when using the melt-albedo feedback. A revision of the presentation of the study is my opinion needed in order for the paper to be published, but I think it is a matter making sure that the conclusions are discussed in the right context. See my comments below:

General comments

My impression of the manuscript is that conclusions are drawn on the mass loss due to the melt albedo feedback in general. This is, in my opinion, a job for a focussed study using an advanced (regional) climate model. I suggest to alter the focus of the manuscript to investigate the effect of adding the melt-albedo feedback in PISM projections. As an example changing the following sentence from the conclusions:

"Using PISM-dEBM-simple we find that the melt-albedo feedback can lead to additional 12 cm sea-level equivalent of mass loss in RCP2.6 and additional 70 cm in RCP8.5 until the year 2300"

to something like this:

"Using PISM-dEBM-simple we find that the melt-albedo feedback can lead to additional 12 cm sea-level equivalent of mass loss in RCP2.6 and additional 70 cm in RCP8.5 in the projected mass loss from PISM until the year 2300"

The model performance is investigated from many different angles, but I think a comparison between using dEBM-simple with using the simple pdd module, on the MAR historical time series, could add some insights into that dEMB is actually a more physically based model - that as is also shown also makes it possible to make more realistic experiments further back in time where pdd factors are certain not to be the same, as is shown in the Eem experiment.

Abstract:

Page 1

Line 1- 3: The melt-albedo feedback that is investigated here is only on the snow part of the ice sheet.

Line 3: add a sentence like: In order to test the effect of melt-albedo feedback in a prognostic ice sheet model, we implement...

See also general comments about focus of the conclusions.

Introduction:

From reading the introduction, I don't think it is entirely clear what the "-simple" refer to? Does it refer to the simple version of dEBM presented in the 2018 paper or does it refer to simplifications made in this study?

Page 2

Line 5-6: These are in fact areas that are not considered or discussed in the present study, later on this should be discussed in more detail.

Line 7: Replace "As darker snow ..." with something like:
As darker surface absorb more radiation than lighter surfaces, the effect of darkening due to increased melt could trigger...

Line 14: Replace "covered by meltwater" with: at melting point

Line 24-25: perhaps move the references up into the text:
The insolation-temperature-melt equations defined/used by van den Berg and Robinson ...

Line 32: This is the first time you mention PROMICE - you need to add info on what that is. Or rewrite to say that the model showed good correlation with observations.

Page 3

Line 3: Delete "in addition". It is not in addition, but in order to do what you do as you state later in the sentence.

Line 7: This is the first time you mention MAR - spell it out and add references

Line 18 - 19: "PISM was shown ..." I guess this is actually mostly true when run on a spatial grid below 1km. Here you run on 4.5 km (and that is completely fine for this purpose), but perhaps state the resolution issues here somehow.

Methods

The parametrisation of the melt-albedo feedback is the weakest point of the study, and care should be taken that aspects of the consequences of the simple melt-albedo feedback parametrisation are discussed thoroughly perhaps already in the methods section. For example - has this been done in other studies before? Discussion of in particular the melt-albedo feedback parametrization is needed in order to be able to draw any conclusions of

the contribution of this to the ice sheet mass balance. After reading the methods section I have questions such as: What are the consequences of only looking at the snow zone - and thereby neglecting albedo increase in the bare ice zone? Where has the ice sheet been observed to have the α_{\min} value that the study is using? How large is the part of the ablation zone that is snow covered compared to the bare ice zone?

Page 3

Line 32: "We neglect ..." Do you allow for shelves when you have fixed calving front position?

Page 4

Line 9-11: I think this becomes a bit confusing. I suggest that you consider the following two paragraphs as the place where you introduce all the different parts of equation (1). This means that you do not need to mention albedo and transmissivity in line 9, as you will go through them later and the following sentences describing c_1 and c_2 , should go down after you introduce T_{eff} .

Page 5

Line 17: Does this basically mean that the transmissivity is an average over 2019? A sentence or two of what this actually means in relation to the real transmissivity would be informative in order to understand the prognostic potential of the parametrisation.

Line 24: Perhaps mention here what you then neglect by introducing the linear relation, like effect of clouds.

Line 28: delete the sentence starting with "Regional climate models..." And start next sentence with something like
"Snow albedo in MAR is calculated using a snowpack model, explicitly ..."

Page 6

Line 1: The sentence starting with "Ice albedo ..." could be rephrased to:
"In MAR, ice albedo is explicitly ..."

Line 6: add information about MAR version and reference to data

Line 7: "Allow us to capture melt processes". I am not sure exactly what is meant here

Line 9: Introducing α_{\min} : This means that you do not consider the darkening of ice at all. This should be pointed out somehow, maybe here or somewhere else, but it is an important point, and also, have α_{\min} been observed at anytime across the ice sheet during melt events?

Line 18: Is the geometry kept fixed?

Line 20: perhaps just write that precipitation is kept constant - instead of writing that it is not scaled...

Line 25-31:

I think this needs to be elaborated. You do this calibration experiment where you do not use PISM-dEBM-simple but force with the data that you have parametrized.

I think this is more or less what it already says, but I think it needs to be reformulated.

You need to explain why you do the Eem test? I suppose it is to test the sensitivity to insolation values - but it needs to be clearer.

Page 7

Line 4-7: Rephrase: Does these monthly temperature fields come from MAR? And where does these scalar temperature anomalies come from?

From line 8: I would like to have the reasons for each of the experiment series before the method is describe. Basically moving the information from page 8 line 8-20 up.

Would it somehow be possible to group the experiments into four groups, so that it is easier to follow which group of experiments that are being discussed in section 4?

Page 8

Line 21: Should this title refer better to sec 2.5? By using the word calibration perhaps?

Line 22-23: I am missing a sentence like: As described in the Calibration experiments in the methods section?

Section 3.1:

This section is not completely clear to me. Perhaps spell out a bit more what is calibration and what is validation.

Line 27: Is this an experiment? I thought perhaps it could be called a calibration run?

Line 31: The root mean square error of what field? Melt?

Page 9

Line 4: Maybe add a sentence here to sort of conclude that using the RMSE method described, you find the parametrisation constants?

Line 5: "Yearly total melt computed with PISM" While using the dEBM-simple method?

Line 12: Could this also relate to the fact that you do not consider the darkening of ice?

Page 10

Section 3.2:

I think that it needs to clarified throughout the text that this experiment is done to test the sensitivity to the orbital parameters (or something like that).

Page 11

Line 4: clarify which historic variability?

Line 5-6: "This is in line with ..." So I guess this is the point of the experiment - basically to test if you get similar results to others.

Section 4

It would be nice if it was clear here which of the experiments are being discussed. Perhaps if they are put into four groups as suggested above, this would be easier.

Keep in mind that the resolution of 4.5km actually prevents the model from resolving the ice streams properly - this could have an influence on the surface-elevation feedback. Then on the other side, the fixed calving front must add some effect of inducing ice streaming.

Page 12

Line 1-2: Needs to be rephrased. Here the lower bounds of the experiments in this study. It is a lower bound for the model ice losses. I do not believe that this model set-up is able or discussed to high enough detail to give the lower bound for actual ice losses.

Page 13

Line 1-2: "But also ..." rephrase sentence

Line 7: By this point I have forgotten the timescales that the experiments are being conducted at. Perhaps remind the reader

Line 9: melt-albedo

Line 11-12: Explain why the melt-albedo feedback becomes less important with time? I suspect that this is due to the fact that the entire ice sheet gets the minimum albedo.

Page 15

Line 23: Reducing the frequency how? I think actually, the frequency is really interesting. What effect do we get if we get more extreme years like 2012, and with this module this could actually be tested. And why do you think June is most sensitive to darkening?

Discussion

I like the discussion, and it shows that considerations

Page 16

Line 15: Sentence starting with "This is because..." Perhaps the sentence should be slightly rephrased, however, this is the kind of reasoning I think is missing in the two sections above.

Line 30 - page 17 line 4: Paragraph starting with "Therefore the only ..." This is a great paragraph and it really frames the whole study.

Page 17

Line 6-7: Perhaps mention why the model overestimates early melt and underestimates late melt.

Line 17-18: "It is a coarse representation of what is important of the albedo of snow and ice". Actually it is only a representation of the albedo of snow - as the minimum albedo is clean ice?

Conclusion

Page 19

Line 11-12: I think this sentence could be expanded to something like: Using dEBM-simple we find that the melt-albedo feed back can lead to additional 12 cm SLE ... in the projected mass loss in PISM.