

Anonymous Referee #2

This manuscript presents the coupling of the GRISLI ice sheet model with the atmospheric component of the iLOVECLIM model. This tool offers great potential for simulating past climates and ice sheets. Whilst the current manuscript is interesting, useful and well written (apart from a few sentences here and there), it requires a bit more precision in the description of the coupling (especially with regards to orography and ice extent), more results, and a comparison of the coupling procedure and results with other similar models in the literature (unless this will be done in a separate paper).

MAIN COMMENTS Methodology:

-How are the ice sheet model parameters chosen? Please indicate a reference for the calibration of the ice sheet model. What was the calibration target ?

We used the same parameter set as the one used in Peyaud et al., 2007, as was mentioned not very clearly in the previous version of the manuscript. It is now modified to express that the model was improved for northern hemisphere studies. In Peyaud et al., 2007, it is unclear how the calibration of each sub physical mechanism was done, but the resulting European ice-sheet is in good agreement with reconstructions of past ice-sheet extent. We have added a sentence to the manuscript highlighting this fact: *“GRISLI is used with the same parameter set as in Peyaud et al. (2007). The resulting Eurasian ice-sheet extent was found to be in good agreement with reconstructions of the Early Weichselian.”*

-p5225 section 3.4 l16 : The orography on the GRISLI grid is aggregated to the ECBilt grid considering the closest (in distance) ECBilt cell center.” What does aggregated mean here ? This section needs more detail for reproducibility.

We just use all GRISLI cell centers that are located in one ECBilt cell and average the values onto the ECBilt grid. We modified the sentence as follow: *“The orography is averaged onto the ECBilt grid as follow: all GRISLI cells contained in one ECBilt cell are averaged using a simple mean.”*

-How do changes in orography influence ECBilt ?

As any change in topography, it will affect the atmospheric wave patterns, the surface temperatures, the river routing etc. We do not understand clearly what the issue is here. Such features are common to all atmospheric models when topography is modified.

-L17: You haven't mentioned how you interpolate the ice mask onto the ECBilt grid, nor what the surface properties of ice surface are in ECBilt (eg albedo). Does the albedo change if the surface is snow covered ? We have modified the text to include that the icemask is averaged on the ECBilt grid with the same method as for orography (simple mean). A sentence was added that reads: *“The icemask is averaged onto the ECBilt grid as is done for the orography.”* The albedo is dynamically computed, so it is changed indeed when the surface is snow covered. We have modified the text on the albedo computation also in response to a request of reviewer #1, that now reads: *“The surface albedo in ECBilt is then computed from the icemask provided, as in the standard LOVECLIM model.”*

Offline ice sheet: One result missing from this paper is the effect of simulating the ice sheet with a two way coupling as opposed to a one way forcing. I think the authors should run the ice sheet model offline with the precipitation and temperature forcing of CTRL and compare this ice sheet with the ice sheet in SNOW. Also, how does the GRISLI ice sheet look when forced with temperature and precipitation from the climatology ? We need to see these results to understand the effect of the ice sheet model uncertainty/calibration and approximations on the ice elevation and extent.

Following this request, we have performed three additional simulations: CLIMICE (offline equilibrium with the climatology) PRECIP-SO and SNOW-SO (Semi-coupled simulations with iLOVECLIM where the ice-sheet feedback on the atmosphere is turned off). The results of the three simulations have been added to the revised version of the manuscript and the effect of the coupling back to the atmosphere is now discussed more thoroughly. The text was modified in many sections to account for these changes (in particular in experimental setup, results and discussion).

Mass balance :What is the effect of the temperature and accumulation biases on the mass balance of the ice sheet. I would like to see a more in depth discussion of the ice sheet mass balance here. How much is the accumulation overpredicted by? How about the effect of the warm bias on melting ? How long is the melt season ? Context of this study: There isn't any comparison of the results with similar studies. There has been other coupling between climate models and ice sheet models (eg Fyke et al) published in this same journal. Please compare the coupling procedure and results with other such studies.

Following a similar request from reviewer #1, we have now added the Surface Mass Balance in all simulations into the manuscript. Overall our results show that the accumulation is overpredicted due to too high accumulation (that more than compensate the warm bias). The results are discussed in a dedicated new section on surface mass balance.

It is rather difficult to discuss the SMB with respect to other studies because of the different units etc. A discussion with respect to other studies was done in the new version of the introduction with respect to general coupling methods. In general, our simulations are close to those reported by Quiquet et al., 2012 for the LMD-z atmospheric general circulation model, in terms of simulated ice-sheet thickness when forced offline except for the precipitation biases, since our model is warm and humid instead of warm and dry. With respect to Fyke et. al., some of the coupling approaches we use (like the vertical downscaling of temperatures over sub-grid elevations) are similar. At the opposite, we adopt a non-bias corrected approach in contrary to Fyke et al. This has been added into the introduction text as well.

More minor comments and suggestions:

P 5216 Line 26 : I suggest replacing "climate model" by "Earth system model".

The introduction has been completely re-written following request of reviewer #1. The cited quote does not exist in the revised version.

P 5217 l3: "Hence, : : ." this sentence is missing a verb

The sentence was modified accordingly: "This is why we chose a model that.."

P 5220 l3: "Ice stream regions are determined for the saturation of the sediment layer as described in Peyaud et al. (2007)." I don't understand this sentence.

The sentence has been modified in the revised version as: "The location of the ice streams is determined by the basal water head, with ice streams regions corresponding to areas where the sediment layer is saturated (Peyaud et al., 2007)."

P 5220 l6 : can you give more context to the description of the calving procedure. Why do you use option (b) ?

There is a misunderstanding here. The text says "Calving at the ice-shelf front occurs when two criteria are met: [...]" We do not choose a) or b), it is only when a) and b) are met at the same time on the same grid point that calving occurs. The criteria was built from observations in present-day West Antarctica. We have modified the last sentence of the paragraph to hopefully clarify this fact: "That method is built from present-day observations and yield ice shelves similar to observations in West Antarctica when applied to the Antarctic ice-sheet (Ritz et al., 2001)."

P5221 l1: the ice sheet model is described as isolated with respect to the CLIO model. What is the implication for the precipitation falling on the ice sheet. Is it re-routed to the nearby oceans or does it accumulate on the ice sheet ?

Again, the sentence was misleading. It is now removed. A new figure (fig. 4) was added to fully describe the exchanges of energy, water etc. between the different components. The figure is discussed in the text.

P5221l3: "at the opposite to" -> as opposed to

That sentence does not exist in the revised version.

P5221l5: "This is an important requirement to consistently use the model in climate diin~A~ erent from the present" The use of "consistently is a bit confusing in this context. Prefer "This is an important requirement to be able to use the model to simulate climates diin~A~ erent from the present in a consistent manner"

Changed according to suggestion.

P5222 section 3.2: why does the interpolation involve 15 surrounding points, I can only count 8 in a square grid. Is this because of the spectral grid ?

This was also noted by reviewer #1. It was a mistake and is now replaced by "4 neighbouring" points. In

fact, depending on the distance allowed for interpolation, one can use 4, 8, 15 etc. surrounding points. In the present work, only the 4 closest are used.

P5224 Can you provide a plot of the temperature gradient/lapse rate or some numbers so that we can put it in context of other modelling frameworks ? How does this compares to data ?

This is now done in a new figure and a new paragraph in the text. Here is the lapse-rate figure:

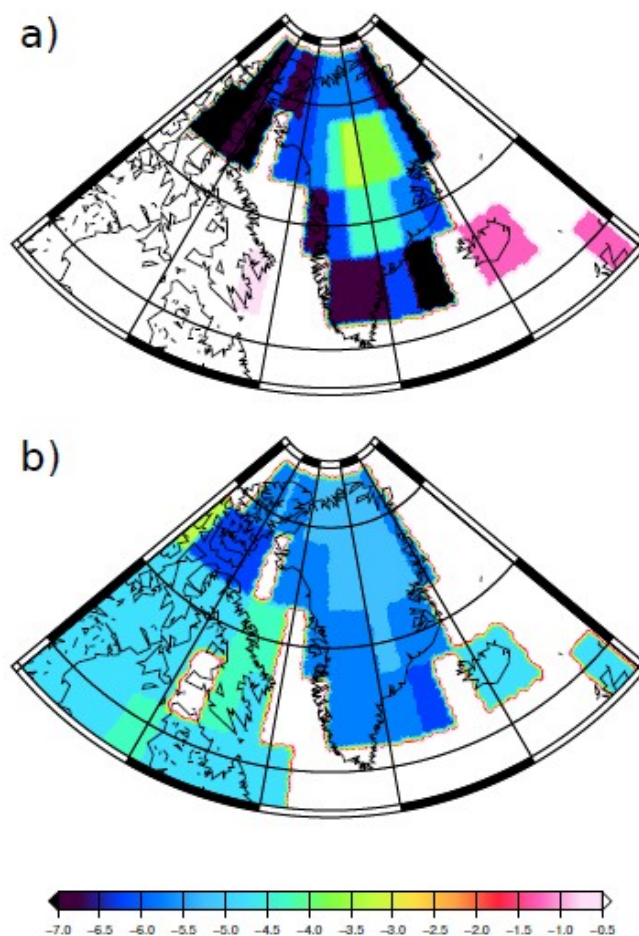


Fig. 7. Calculated lapse rates within the downscaling procedure, in degrees per km. a) is for February, b) for July. The computation of the lapse rate involving a linear regression over three temperature points, there is no lapse rate calculated when the correlation coefficient of the regression line is too low: hence the large white areas over north America in panel a).

P5225: see previous comments

See previous answers.

P5226 l1: rephrase "This enables to"

P5226 l23: "Differences between the CTRL and the SNOW or PRECIP experiments are due to the inclusion of ice-sheet dynamics and its feedbacks." I disagree with this statement. The ice sheet in CTRL is not at equilibrium with the climate, or rather the climate is not compatible with this ice sheet. The difference in ice sheet size is what causes the differences in the climate. In this sentence is a bit misleading, especially since the difference in shape of the ice sheets is more to do with the surface mass balance here, rather than ice dynamics.

This is perfectly exact. In fact, that is exactly what the three coupled / uncoupled simulations are showing. We have replaced that part of the text with a discussion of all simulations (CLIMICE / PRECIP/SNOW-SO and CTRL, SNOW/PRECIP). The entire section was mostly rewritten.

P5227 l1 : Is the observed ice sheet plotted on the GRISLI grid in figure 6 ?

Yes it is. This is now specified in the new version of the legend of the manuscript (now figure 9): "*a) Observed Greenland thickness (Bamber et al., 2001), interpolated on the GRISLI grid*"

Section 4.2. Please comment on which accumulation treatment is preferred (SNOW or PRECIP). The results shown wouldn't allow us to discriminate one, but the authors might have a preference or some insights to give here.

We now argue in the Conclusion section that the SNOW setup should be preferred since it allows to switch between snow and ice using temperature every four hours instead of every month, and thus avoid the parametrization of monthly temperatures below 2°C.

5228l19: Again I don't like the use of "dynamical" here. It's not representative of the difference between PRECIP and SNOW.

The cited sentence has been removed.

P5229 l27: "iLOVECLIM do not exhibit large systematic biases when looking at the Greenland area" Some would say that 2degC and even 5degC error is a large bias! In general in the manuscript, try not to overstate the match with observations.

A bias of 2 to 5 degrees is not uncommon, as shown for example in Quiquet et al., 2012. Even much higher resolution model like the MAR model have temperature biases of that order of magnitude. Incidentally, this is still within the variability of the observations (cf. Quiquet et al., 2012, figure 7). What we meant here is that there is no consistent bias over the Greenland ice-sheet since parts are overestimated and parts underestimated. Thus, we have modified the sentence that now reads: "*In the CTRL configuration, iLOVECLIM does not exhibit a coherent, systematic bias over the whole Greenland area (Fig.~\ref{fig5_marianne}a and~b).*". A sentence was further added: "*Biases discussed above are of the same order of magnitude as the ones obtained with low resolution General Circulation models \citep{quiquet12}.*"

5230l14: triggers -> causes

Done as suggested.

p5231 l 19: "Aspect" to what ?

We replaced the word by "Another direction to look at"

p5231l25: What does this last sentence mean ?

That sentence was removed.