Reviewer 1

GENERAL COMMENTS

1. The ablation simulated through the positive-degree-day (PDD) method is compared to the ablation as simulated by the surface energy balance approach (SEB) in the coupled climate and ice sheet model set-up. Another ablation scheme that is currently quite popular is the insolation-- temperature--melt (ITM) approach (see for example, Robinson et al., 2011; Robinson and Goelzer, 2014). I understand that additionally assessing this melt scheme would be a lot of extra work, but this alternative approach should as least be mentioned and referred to in the discussion. One of the likely reasons why the PDD method cannot perfectly capture the SEB simulated ablation evolution over long time scales (such as a glacial cycle) could be because it does not account for insolation changes. The ITM method does include the effect of varying insolation on melt (although it might have other drawbacks). Please discuss.

Indeed, several years ago we developed the regional model REMBO which is based on ITM approach and we used REMBO in a number of publications. However, it is important to note that REMBO was specially designed for Greenland and for climate conditions which are not very different from present. The ITM scheme contains apart from two empirical parameters, which are likely spatially and temporally dependent, one parameter – transparency of the atmosphere - which is known to vary strongly spatially and in time. We have no idea how ITM can be parameterized for the purpose of simulations of large scale glaciations during entire glacial cycles. Therefore we never used ITM for this purpose. And, although, ITM does have some advantages over the PDD approach, we do not believe that ITM can be considered as the real alternative to the physically based SEB approach.

2) I also miss a section in the introduction explaining the time period you focus on. Explain why the last glacial cycle, and give some background information. Introduce terms like inception, termination, LGM, and Holocene. And give dates for your "target windows", and call it "target periods" or similar.

3) Also lacking is a discussion of your reference simulation with respect to geological reconstructions of the ice sheets over the last glacial cycle, and other modelling approaches.

The choice of the last glacial cycle is rather obvious – it is best covered by paleoclimate records, especially since the LGM. This is why most of previous modeling study of glacial cycles have been performed for the last glacial cycle. As far as our model performance for the glacial cycle is concerned (reference run), it has been described in detail and compared with available climatological data in Ganopolski et al (2010). Our reference run is practically identical to that model which is analyzed in Ganopolski et al (2010). We just refer to that paper which was published in open access journal and readily available for any reader.

4) The set-up of the "offline" and "online" PDD ablation methods need to be explained in more detail (e.g. page 4, line 25).

We will describe the difference between "offline" and "online" simulations in section 2.3 more clearly.

5) *Discussion resolutions: what is the effect of the rather large grid boxes used in CLIMBER and SICOPOLIS?*

We do not believe that the manuscript under consideration is the right one for discussing the resolution issue. We and other groups around the world have already published ca. 200 papers based on CLIMBER-2 model. In many of those papers an extensive comparison of CLIMBER-2 results with observed present, reconstructed past and simulated future climates by GCMs is presented. These studies revealed that on its resolution CLIMBER-2 is doing a reasonably good job. The coupling between the coarse resolution climate component of CLIMBER-2 and the relatively high resolution (70km) ice sheet component is, indeed, a nontrivial task to which we devoted significant efforts. The coupling is based on spatial and vertical interpolation and, additionally, parameterization of sub-grid processes, such as orographic precipitation. This is described in detail in Calov et al (2005) and Ganopolski et al (2010). Obviously, using a higher resolution is always desirable but for simulations of glacial cycles a high spatial resolution is costly. At present the CLIMBER-2 model is the only comprehensive Earth system model which is able to simulate numerous glacial cycles. Therefore we cannot compare it with the results of higher resolution models. For readers not familiar with previous works made with CLIMBER-2 we will add a paragraph in the Introduction section discussing potential caveats related to coarse spatial resolution of our model.

6) Also, the PDD method is originally developed for daily temperature input, as are the literature values for PDD factors and the standard deviation for temperature. You use 3 - day mean temperatures. Please discuss.

In fact, PDD methods are developed for using climatological monthly temperatures which are then interpolated to produce daily temperatures. Therefore calculation of PDD by use of a 1-day or 3-day time step produces essentially the same result. In CLIMBER-2, the time step in the physically based EBM is three days. This is done to reduce computational cost. This is why we used the same 3-day time step for calculation of PDD. Of course, the factor 3 was taken into account when we calculated PDD. This issue will be clarified in the revised manuscript.

7) What are the initial conditions for the (reference) simulation(s)? Same as pre-industrial? Does that mean only ice on Greenland (how much?), or where else? A map of the inital ice distribution for the reference simulation would be helpful.

In all our experiments the equilibrium state of the climate-cryosphere system obtained for present-day conditions was used as initial condition and the model was run from 130 kyr BP until the present. We now clarify this in the text. Since the simulated preindustrial climate looks very much alike the observed present-day state containing the Greenland ice sheet as the only ice sheet in NH, we do not believe that such a figure would be very useful.

8) *Basing the selection of the PDD factors for the online simulations on the best PDD factors for the offline simulations is not very convincing. I though the whole point was to show that interactions/feedbacks between the climate and ice sheets are important. Why not test a range of factors, and select the best through some statistical evaluation, such as the rms-- error approach used for the offline simulations?*

First, we believe that using of the “best” PDD factors found in offline simulations for online simulations is a rather natural choice. Second, importance of feedbacks between climate and ice sheet is well known and is not the point of our study. The main result of our study is that it is not possible to find a pair of PDD factors which are suitable for simulation of the entire glacial cycle. We would like to clearly say that we did not try to find the best PDD factors which we would recommend to other modelers to use. To the contrary, the conclusion of our paper is very clear – we do not recommend to use the PDD approach for simulating glacial cycles. And this is related to the last general comment:

Some scientists do not have access to a climate model or not the computational resources to run it over long time scales, and therefore do not have access to SEB - derived ablation. Could you give a recommendation on how to best apply the PDD method. I.e. emphasize testing different PDD values, use a short time period, select one ice sheet, …?

Our study shows that a realistic simulation of an entire glacial cycle with the same PDD parameters is not possible. Sure, one can pursue a kind of inverse modeling approach to infer PDD parameters for different time intervals to obtain results comparable with paleoclimate reconstructions. However, the scientific value of such modeling is questionable. As the modeling of individual aspects of a glacial cycle, such as glacial inception or termination concerns, a “recommendation” according to our study is clear. Namely, to simulate glacial inception one has to use smaller PDD values than for simulating glacial termination. But, again, since we believe that our study convincingly demonstrates that PDD is not an adequate method for modeling the ice sheet surface mass balance during glacial cycles, we are reluctant to give any explicit recommendation of how to “improve” the PDD approach.

SPECIFIC AND TECHNICAL COMMENTS

We will address all comments appropriately.

The Figure 4 will be replaced and Figure 6 will be modified according to the suggestions.

Page 8, section 3.2: Why is the entire ensemble discussed for the rms-error, and only a selection for the anomaly/offset m? Figure 4 could be replaced by a figure similar to Figure 5, but than for the anomaly m. The information of the original Figure 4 can also be seen in Figure 6, especially if you add a (blue) line for the PDD-derived ablation evolution of the simulation that fit best to the reference simulation, over the entire 130ka.

Figure 4 will show the bivariate distributions of the mean anomaly and the rms-error calculated for the total NH ice sheet. The new Figure will show that the minimum in anomaly is not constrained by a unique pair of melt factors.

Page 11, discussion of Figure 12 is also not clear , please rewrite.

Figure 12 will be replaced by a new Figure showing time series of insolation and ablation for June and July, as in June insolation is largest and in July ablation is largest. We will present the simulated ablation with the SEB approach in response to snow albedo changes induced separately by snow aging and dust deposition. The new Figures will show results from offline and online simulations and which will be described in the Discussion section.