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Climate of the Past Discussions

Interactive comment on "Modelling snow accumulation on Greenland in Eemian, glacial inception and modern climates in a GCM" *by* H. J. Punge et al.

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We thank the reviewer for his comments on the article. We do agree on his comments in most points and will try to address the proposals made in the corrected version.

In detail, we have the following remarks on the review:

C610, L3-4 (conclusions for past climate limited):

It is true that realistic simulations of paleo climates are still a difficult task, at least at the degree of complexity implied in general circulation models (GCMs). Part of the difficulty arises from missing information on the initial and boundary conditions for the

past periods, and part of it stems from the deficiencies in GCMs regarding processes that gain relevance on long time scales. In the article, we try to document one step forwards in the second category of difficulties, by improving the physical representation of snow which, as we show, is of high importance for the mass balance of ice caps. The present quality of model results may appear disappointing to some readers, but we think the results are useful in particular in pointing at the scale of uncertainties involved in the developments. We will discuss this approach in our new version.

C610, L6-7 (figures):

We will check with editorial staff how figure size can be enhanced and will modify the figures accordingly.

C610, L11-19 (Bigger comments):

We agree that the 126 and 115 ky BP presented here are essentially sensitivity experiments, although we do take into account changes in sea-surface temperatures/sea-ice by using the output from the IPSL coupled model. In a sense, we kept our design consistent with the coupled model experimental design, which did not consider changes in ice-sheet topography. Our main objective was to test our snow model and compare it to the PDD formulation for climates for which we know the seasonal cycle is altered. We will add a note on why we chose this experimental design and its limitations in the new version of the manuscript.

We would also like to remark that there are other major difficulties at hand when trying to develop what the reviewer cites as a 'climate model with physically appropriate coupling to an ice sheet model'. Most notably, there are considerable deficiencies in present day GCMs in correctly reproducing the effect of orography on the general circulation in terms of, e.g., 500hPa geopotential. These will have to be overcome before a detailed representation of the past climates can be obtained, and simulations of paleo climate can be considered realistic.

As for the suggestion to submit to Geoscientific Model Development, we admit that we considered this step as well at one point. However, we concluded that the amount of scientific results, in particular on past climate, as well as on the PDD method and impact of using climatological forcing, justify a submission to CP. The difficulties encountered in the modelling are also of scientific interest and not only of technical nature. We feel that the CP modelling community shall be aware of these issues and the major findings (e.g., the importance of reproducing the ablation zone, the importance of albedo, vertical resolution.)

C610 L23 (error bars):

We will try to be more precise in the text.

C610 L24 – C611 L4 (SMB improvement):

Indeed, at the first look, there is no improvement in SMB numbers compared to the previous model version. But we can attribute the overestimation of melt to the overrepresentation of the ablation zone (model grid spacing > ablation zone width), and so too high an ablation would be an expected result. We also consider that using a realistic snow model will allow to better identify problems in a model, which are often amplified because of the non-linearity of the processes governing SMB, and that may be hidden in a linearised representation of SMB as with the PDD method.

Refreezing is an integral part of the SISVAT model and has been analyzed in detail before (e.g., by Gallée and Duynkerke, 1997). Also, we consider it mainly a function of modelled temperature, and temperature is in reasonable agreement with observations and regional models. For these reasons no output data on refreezing was stored. We consider repeating all simulations for this reason too big an effort compared to the information gained.

C611 L6-21 (resolution and future plans):

Indeed, the cost of running a GCM at sufficient resolution to resolve the ablation zone

may be prohibitive. Nonetheless, the authors feel this should be a goal. The most recent IPCC studies include resolutions that are considerably higher compared to this study. Technological advances will likely make global resolutions at the same order as in present day regional models feasible in GCMs. Adaptive grids are an interesting perspective in this respect as well. The coupling between an AOGCM used for climate studies such as the IPSL coupled model and an ice-sheet model indeed requires a downscaling procedure to compute a valuable SMB on the ice-sheet model grid. We indeed plan to use such a downscaling technique at IPSL, either downscaling the temperatures and then using the PDD method, or, at longer term, downscaling the variables needed for SISVAT and (re-)using SISVAT at the ice-sheet model scale. We did not wish to describe this procedure here because it would introduce another level of complexity. Of course, we have fewer points at the GCM scale than at the ice-sheet model scale, but we believe these points already show a variety of behaviours (accumulation, melting) that would be found at the smaller scale. This will be stated in the new version of the manuscript.

C611, L23-26 (computational cost):

Running the snow scheme with the GCM and present day ice sheets increases the computational cost by approximately 10% relative to the standard version. Given the complexity of the model and the fact that the code and interface are not yet optimised, we consider this a reasonable number. It is operational on all pre-defined ice sheets, and will be used on developing ice sheets once interactive grid cell type adaptation is implemented. Resolution increase is expected to scale linearly with snow model compute time, so we expect the part of the snow model in total cost to decrease. Another snow scheme is developed for the ice-free land surface, as we do not need a model as complex as SISVAT for non perennial snow.

C611, L27 – C612 L2:

We will consider omitting a few plots where possible. This could also make the figures

clearer (hence responding to the second comment above).

C612, 3-7:

We will clarify the text at this point. Indeed, uncertainty should be highlighted.

C612 L8-10:

We will include a comment on this aspect in the text.

C612 L11-13 (atmospheric levels):

The change in vertical levels was necessary to compute more realistic surface fluxes at the ice surface. Indeed, the standard resolution was too coarse to represent surface inversions, even crudely. This information will be added in the new manuscript. Differences between LMDZ4_v2 and _v3 are rather minor, but a consequence of the steady development process of LMDZ. They include technical as well as physical corrections (a detailed list would be out of place here we estimate), but no major changes affecting our comparison. The change of model version was also motivated by a hardware change and resulting technical problems..

C612 L14-17:

We will correct these errors, thank you for pointing to them.

Interactive comment on Clim. Past Discuss., 8, 1523, 2012.