

## ***Interactive comment on “Using results from the PlioMIP ensemble to investigate the Greenland Ice Sheet during the warm Pliocene” by A. M. Dolan et al.***

**A. M. Dolan et al.**

a.m.dolan@leeds.ac.uk

Received and published: 28 January 2015

My co-authors and I wish to thank the reviewer for their careful review of the paper. We have addressed their comments as detailed below.

Reviewer 1 (Bas de Boer) The manuscript by Dolan et al, describes a thorough examination of the influence of the modelled climate over Greenland on the Greenland ice sheet during the warm Pliocene. The manuscript is a follow-up of the PLISMIP paper by Koenig et al. (CPD, 2014b), but here one ice-sheet model (the model BASISM) is used with 15 different realisations of the Pliocene climate performed in the PlioMIP ensemble. I think the paper is well written and the analyses performed are

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thorough and complete. This manuscript describes a good addition to the ice-sheet modelling work performed on the Pliocene and is of a good quality. The manuscript is well structured and the analysis performed on the ice-sheet model and the climate models (e.g. the discussion of the albedo) is clear. I accept this manuscript with minor revisions. Most comments given below are minor and are on rewording of the text. I have one major point, and that is the low influence of the different parameter values on the pre-industrial simulations (Fig. 5). As given in Table 2, the parameter space is quite sufficient to get a nice spread for the Pliocene (Fig. 7), but it is striking to me that this does not occur for the pre-industrial. I think a lower sensitivity could be expected, but no differences at all, whereas mean climatology (Table 3) is quite diverse between models, is something that needs some additional investigation of model output.

Specific comments Page 3485

Line 2: In recent literature this time period from 3.264 to 3.025 Myr ago does no longer apply to the mid-Pliocene but rather to the mid-Piacenzian (e.g. Dowsett et al., Scientific Reports, 2013) or the Late Pliocene. This should be changed throughout the text.

> To retain consistency with the original PlioMIP naming conventions, we would prefer not to use mid-Piacenzian or Late Pliocene as this may be confusing. However, we will describe the rationale behind the naming conventions that we use here.

7: warmer-than-modern could be changed to warmer than present-day climate.

> Done 12-14: Mention here that you have used 15 models from PlioMIP. > Done 18: the surface albedo > Done 21: Be more specific, mention which data. > Data pertaining to ice extent - done 25: Replace these two references with the IPCC AR5 chapters. > References replaced with Church et al. (2013), Masson-Delmotte et al. (2013) and Vaughan et al. (2013)

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13: You could also refer here to Rovere (EPSL, 2014).

> Done

14-18: Mainly due to insolation changed (for the previous interglacial, the Eemian). One could also refer here to Van de Berg et al. (Nat Geo, 2011) on the importance of insolation on melting of ice on Greenland.

> Done

Page 3487

8: Why not refer to Koenig, 2014b here?

> Done

11: Replace 'and' before GENESIS with a comma.

> Done

18: Replace 'ice sheet model' with ISM (this should be replaced a number of times in the text).

> Done in all cases

29: Here, it is first mentioned that 15 different models are used, this could also be mentioned in the Abstract.

> Done

Page 3488

15-16: Acronym of PlioMIP is already mention in page 3486, change sentence to: "...mPWP, PLIOMIP (Haywood et al., 2010, 2011) was initiated ..".

> Done

Line 23 and line 1 on page 3489: Throughout the text you refer to the AGCM as 'Exper-

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iment 1' and the AOGCM as 'Experiment 2'. I understand that this originates from the PlioMIP paper as described in Haywood et al. (2010, 2011a). But in this manuscript it is a bit confusing since you do not run the climate-model experiments but use the output to force one ice-sheet model. I think in this manuscript it is sufficient to just mention the two separate experiments shortly in this section (2.1) and then in the remainder of the text state either AGCMs or AOGCMs and not use Experiment 1 or 2.

> Done in all cases

Page 3490

8: Acronym of BASISM already given on page 3487, just state BASISM, without brackets.

> Done

19-20: What do you mean with 'following Hill (2009)'? Do you use the same methods as described in that study? Please explain and rephrase sentence.

> Done

Page 3491

23: Remove 'atmospheric'.

> Done

Page 3492

27: "... for each model simulation."

> Done

Page 3493

1: Change to: "... each simulation reconstructs the observations of ice thickness."

> Done

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1-2: Add 'the' before 'normalised'.

> Done

2: Explain here what you mean with the normalised RSME.

> The measure we have used is actually simply RMSE – normalised has been removed and the text altered to: "RMSE describes the magnitude of the differences between two fields (e.g. observed ice thickness and simulated ice thickness). In both cases, lower values describe a better match between the modelled and the observed GrIS."

19-25: In the discussion of the precipitation of the models, rather start with discussing all GCMs instead of only mentioning MRI.

> Sentences have been rearranged accordingly

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5-9: It is surprising to me that there is so little difference between all the experiments. I think this should be checked since the parameters in Table 2 are quite different and the Pliocene experiments do show this strong variability.

> In this ISM framework, there is a low sensitivity of the pre-industrial GrIS to parameter choices concerning mass balance. We interpret this to be a function of the fact that the modern ablation zone is constrained to the steep slopes on the periphery of the ice sheet. While we fix the grounding line at the modern extent (as our model does not explicitly simulate ice calving at the margins), so ice does not expand out to the ocean, we also have a build-up of ice in the central regions of the GrIS. Therefore, there are little differences between each of the ensemble members as no combination of parameters causes significant melting of the pre-industrial GrIS. Whilst, there is discussion as to the inclusion of a precipitation correction to reduce our bias towards large ice sheets (see text inserted based on comments of reviewer 2), this has not been included as any correction remains uncertain in palaeoclimates. It should also be noted that BASISM performs on par with other SIA ISMs under similar pre-industrial

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conditions (see Koenig et al., 2014b).

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7-9: Replace 'No' with Not', rephrase sentence, perhaps last part first.

> Done

10-13: There are 2 metrics involved here, so also mention the difference in volume.

> Done – differences in the volumes of the simulated pre-industrial GrISs has also been included.

14: Missing Ritz, 1997 in reference list.

> Done

19: Change to: (Fig. 1 in Dowsett et al., 2010).

> The reference to Figure 1 in the manuscript is correct

23: Please read the statement in Robinson et al., (2011): page 393, right column the second to last paragraph of the Conclusions (starting with “None of ..”), i.e. a realistic modern realisation does not necessarily mean a realistic Pliocene simulation.. A short discussion similar like this would be appropriate here.

> We have added a short discussion on this into the manuscript where we discuss the limitations of this approach to allowing us to define the most likely Pliocene GrIS. “A final caveat to this research is derived from the uncertainty as to whether a good simulation of the modern GrIS (when compared to observations) necessarily implies a realistic representation of the Pliocene GrIS. Robinson et al. (2011) found that when simulating the Eemian GrIS (where significantly more constraints are available than for the Pliocene), the ISM simulation that gave the most realistic modern ice sheet, gave an entirely unrealistic ice sheet for the Eemian when compared with data. This highlights the need for further palaeodata constraints regarding the extent and thickness (where

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possible) of the Pliocene GrIS in order to thoroughly assess the results presented here.”

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10-11: Refer here to Fig. 7 (the red dots) as the model simulations that are used for these maps, as is also done in the caption of Fig. 9.

> Done

Page 3498

6: Change ‘balance of energy’ to ‘energy balance’.

> Done

6: Why mention global heat, rather point out how it changes over Greenland.

> The studies that we are referring to here only consider how the global balance of energy changes under past conditions. Later we go on to discuss how the energy balance might be altered over Greenland.

Page 3499

23: What do you mean with ‘differing degrees’, please rephrase.

> The study by Koenig et al. (2014b) suggests that the Greenland ice sheet is very sensitive to changes in SSTs prescribed in a climate model and that this response is mainly due to temperature changes over the ice sheet. Conversely, Hill et al. (2010) suggest that the ice sheet response is minimal and where it does occur, is dominated by changes in precipitation. The phrase ‘differing degrees’ has been elaborated upon, but it is also noted that this studies are not directly comparable as they use different modelling frameworks and different initial conditions.

22-26: Too long sentence, please rephrase to two sentences.

> Done

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7-11: Looking at Figures 10,11 and 12 it seems to me the largest differences occur for the MRI models (both the AGCM and the AOGCM). This should be mentioned/discussed here as well.

> We have refrained from a thorough discussion of the MRI ensemble member here, as understanding the differences in this climate model is beyond the scope of this paper. However, we have mentioned that MRI is an outlier in the PlioMIP ensemble in terms of its representation of clear sky albedo.

9-11: Rephrase to: “Whereas using CCSM4, which . . . summer, produces one of the largest predicted ice sheets”.

> Done

Sections 4.2 and 4.3: Nicely written

19-21: There is no recent publication that could be used instead of ‘personal communication’?

> No, this work was originally published in 1989 and the reassessment of the work by Anne de Vernal was presented at a conference in 2014 but is yet to be published.

26-27: An additional note could be added here on which kind of data, with appropriate references.

> A brief note regarding which kind of data has been added: “Clearly however, there is a critical need for further data pertaining to ice extent (e.g. Bierman et al., 2014) or potentially the Greenland climate (such as vegetation records) in order to more accurately constrain this reconstruction.”

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> Done

> Done

Tables

Table 2: Just wondering why you have chosen for the PDD factor of ice from 5,6,8 and 14 and not a linear rate (like the other two parameters) like 5,8,11 and 14? Please clarify your choice of parameter space.

> The reviewer is correct that the PDD factor of snow and the lapse rate have been sampled at a linear rate, however the PDD factor of ice has not. We wanted to sample an appropriate range of PDD factors for ice, so we used the end members referenced in most studies (e.g. 5 and 14 mm day<sup>-1</sup> degC<sup>-1</sup> – although the study of Lunt et al. (2008a) used an unrealistically high value for ice 64 mm day<sup>-1</sup> degC<sup>-1</sup>. We also wanted to use PDD factors which most frequently were cited in the literature and also used previously within BASISM (e.g. 6 and 8 mm day<sup>-1</sup>). We do not anticipate that our sampling strategy will affect the overall conclusions based on the results presented in this paper.

Table 3: Explain in the caption the exact region used for these numbers, all land area or only all ice-covered area? Perhaps change the unit of mean annual precipitation to mm per year? (a bit easier to grasp for a meteorologist at least..).

> In the original submission we had defined the Greenland area using the region between 25°W to 60°W and 57°N to 85°N. However, as this also incorporates area of ocean, we have now amended our values to be representative of the land area only. The Greenland land area is defined by the land-sea mask given to each of the climate models. All numbers in Table 3 have been amended accordingly and text which refers to the absolute values has been changed. The unit of mean annual precipitation has

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not been changed as in its current state (mm per year) it allows for easy comparison between the precipitation values over Greenland shown in Figure 3 and the global precipitation values presented in Haywood et al. (2013) and other PlioMIP summary papers.

Table 4: State in the caption that these are differences, and between what and what? Differences in the Maximum ice thickness (in km?) seem a bit odd to me, and are these actually used in the text? Please explain.

> The differences have been explained in the table caption and the maximum ice thickness differences have been removed entirely as they are not referred to in the text.

Figures

Figure 5: Perhaps check SMB In the same way? If I look at the precipitation and temperature in Table 3 and Figures 2, 3 and 4 this should be quite different. . .

> The SMB shown in Figure 5 is correct and depicts the areas of ablation and accumulation calculated at the first model time-step (before a lapse rate correction has been applied). Figure 5 and 7: Could you show the modern and PRISM3 volumes in these figures by e.g. a horizontal dashed line?

> Done

Figure 12: Replace Experiment 1 and 2 (Exp1, Exp2) with AGCM and AOGCM, respectively.

> Done

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Interactive comment on Clim. Past Discuss., 10, 3483, 2014.

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