

## ***Interactive comment on “Impact of millennial-scale oceanic variability on the Greenland ice sheet evolution throughout the Last Glacial Period” by Ilaria Tabone et al.***

### **Anonymous Referee #2**

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Tabone et al. use a three dimensional hybrid ice-sheet-shelf model forced by oceanic fluctuations derived from paleo records. The work studies the role of millennial scale climate variability in ocean-ice sheet interaction and is a topic that is of great interest to the glacial climate variability. These type of studies provide a basis to test our earth system models under past climate conditions in order to validate projections of anthropogenic climate change or to develop a better process understanding of climate components that are critical for assessing future anthropogenic climate change.

The introduction provides a nice review of the literature on the subject and reviews the key research questions on ocean-ice sheet interaction. The major problem problem I

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see with the ocean-ice sheet coupling is that the oceanic forcing is not realistic and the study would be better suited to investigate the sensitivity of the model to marine shelf instability as a result of sub-surface temperature variations. Page 11, Line 22 states that the model seems to lag Heinrich Events by 2-3 ka. The manuscript goes to great length to compare the model with sediment cores when the forcing (Figure 1c) is representative of surface temperature changes. The authors state that (Page 12, L2) that they do not aim to precisely reconstruct the timing and spatial distribution of ice discharge during D-O events. I don't think it is satisfactory to show that oceanic millennial scale variability is influencing the GrlS evolution alone unless something can be said about a process based explanation of what is happening in the real climate system based on the modelling results.

Other comments:

Section 2.1 Page 4, Lines 15-31: The description of coarse grid points is not clear here. In line 30, the ice sheet model is given (20x20km) but the ocean resolution forcing is not described clearly.

Section 2.1 and 2.2: P4, L31-32; P5 L2; P13 L13 The statement “we consider the atmosphere as modulated by orbital changes”. This statement should be rewritten to downplay the impression that there is an atmosphere in the model. Statements such as L31-32 that describe millennial variability in the atmosphere are also misleading. One mainly thinks of atmospheric dynamics in terms of atmospheric climate/weather variability which happens on short timescales. Trace gases, insolation and other slowly evolving atmospheric properties are the result of the internal and external forcing of the earth system.

Section 2.3 P5 L26: "... changes in ocean temperature into..."

P6 L4-7: The construction of beta is a nice measure of millennial scale variability. But if you really want to influence the basal melt rate during the glacial as proposed by some of the studies in the introduction in a realistic fashion the millennial index in Figure 1c

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should be inverted to reflect changes in subsurface temperature during Heinrich and D-O stadials. This is a major problem with the study. There is some of this discussion in Section 4.2 on Model limitations and caveats but this detracts from realism of the science and what the study can actually say about what processes are important for millennial scale variability.

P6 L7-8: What is meant by the statement that both  $\Delta T_{orb,ocn}$  and  $\Delta T_{mil,ocn}$  are both assumed to be in phase with the atmosphere when there is no  $\Delta T_{mil,atm}$  in equation (1) and (2)

P6 L12: Adding a short description of how changes in RSL on the orbital timescale are prescribed might be more helpful instead of just the reference.

Section 2.4 P6 L15-20: The authors state that the basal melt is dependant on 4 parameters. Another problem I see is in the variation of the parameter changes during the LHS sampling. The reference basal melt is given as  $B_{ref} = \kappa(T_{clim,ocn} - T_f)$  where  $T_f$  is fixed. Equation (6) has  $B$  proportional to  $\kappa \Delta T_{orb,ocn}$ . So variations in  $\kappa$  and  $B_{ref}$  are not independent. Changes in  $\kappa$  will make inverse changes in  $T_{clim,ocn}$  (the mean climatology of the ocean) if  $B_{ref}$  is varied in an inconsistent manner. So am I missing some understanding of the variational procedure or is the LHS sampling (which considers previous choices) taking care of this discrepancy? Again in section 2.4 L5 , it states that parameter values are samples from specified ranges assuming they are independent from each other. Also same thing on P8L17.

P6 L24: " ... on the GrlS evolution by testing..."

P6 L31: language: " This is also supported by estimate of both surface temperature anomalies" By and estimate??? by estimates of both surface temperature anomalies and... This part needs clarification.

P7 L7: "except for the fact that the oceanic changes associated with the millennial scale variability ( $\Delta T_{mil,ocn}$ ) is set to zero"

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P10 L31: small ocean temperature variations?

Figures:

Figure 2: This figure of the cube doesn't provide a clear visual of the distribution. I would like to see a something like figure 4 hear, but since the information is already in figure 4 the paper needs some modification. Figure 2 can be removed but there would have to be some major restructuring of the text in Sections 2.4 and 3.1.

Figure 3a: The black and blue colours are a poor choice as the lines are indiscernible. Contrasting colours would be much better or add more transparency to the lines.

Figure 7, SM2 and SM3: Same colour choice as in Figure 3.

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