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Interactive comment on "Mending Milankovitch theory: obliquity amplification by surface feedbacks" *by* C. R. Tabor et al.

Anonymous Referee #3

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The study of Tabor et al. investigates the relative impact of obliquity and precession forcing on the waxing and waning of early-Pleistocene Laurentide and Greenland ice sheets. One of the key findings of the authors is that positive surface feedbacks enhance the ice-volume response to obliquity forcing over precession. This suggests that the current understanding of Milankovitch theory, which emphasizes the role of summer insolation, might be misleading. Instead, the integrated impact of insolation over a full seasonal cycle is found to be important, thereby increasing the influence of obliquity.

The manuscript of Tabor et al. is short and concise and contributes to our understanding of the impact of orbitally induced changes in insolation at high latitudes. However, the surface feedbacks stated to be important in enhancing the ice volume response to obliquity are not investigated with sufficient detail. Further, the relative importance of

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the feedbacks involved and possible biases in the results introduced by using a slab ocean are not addressed.

These concerns, as well as the following comments need to be addressed in order to improve the manuscript:

GENERAL COMMENTS

The main conclusion of the manuscript is based on the amplification of obliquity forcing by surface feedbacks (ocean heat, sea ice and vegetation). The impact of these feedback processes should be addressed in detail, as well as their relative importance. One way to accomplish this is to include sensitivity experiments investigating each of the feedback processes separately.

The atmospheric model used includes a slab ocean model. According to the authors the absorption of heat by the ocean is one of the key process giving an amplified response to obliquity forcing. How the exclusion of the deep ocean as well as ocean dynamics impact this result should be addressed in detail.

As stated in the manuscript, the simulated ice volume changes are very small compared to early-Pleistocene proxy records. How would a larger simulated initial (or minimum) ice volume impact the results and the relative role of obliquity and precession?

SPECIFIC COMMENTS

page 3772, line 4: missing ref for GENESIS model and lack of details regarding slab ocean model.

page 3774, line 10: it is stated that “Because the obliquity cycle generates variations in annual- mean insolation, the high-latitude oceans absorb a greater range of insolation annually from obliquity than precession”. However, this is not a sufficient explantation for why the ocean response to obliquity at high latitudes is greater than for precession. This needs to be elaborated. A nonlinear response to seasonal insolation (dominated by precession) could give a large annual mean response (see e.g. Huybers & Wunsch,

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GRL, 2003).

page 3774, line 15: it is stated, but not shown, that the simulated sea ice coverage changes are an indirect response to changes in absorbed insolation by the ocean. The alternative is that the sea ice cover is impacted directly by insolation, thereby giving a change in absorbed insolation by the ocean. This should be addressed.

page 3775, line 16: it is stated that the response of the vegetation is due to changes in annual-mean insolation. It is not made clear why this is, and why seasonal insolation is less important for vegetation. This should be addressed.

page 3776, line 27: it is stated that differences in the meridional fluxes of heat and moisture between orbits is less important than local changes. This result is key and should be elaborated by including a figure to support this statement.

page 3777, line 10: please clarify how ocean heat flux, sea ice and vegetation influences the simulated ice volume.

Figure 3b: The simulated symmetry of the decay and growth rate of ice for precession is surprising. This should be addressed in the text.

Figure 1: This figure is very hard to understand and needs to be improved. E.g. for clarity the x-axis in a/d should be labeled, the color of all curves should be mirrored in the y-axis, and the labels of OBL and PRE should be overlain on the respective figures.

TECHNICAL COMMENTS

page 3775, line 6: here a reference to Fig. 1b is given before introducing the contents of this figure. Should specify that it is ocean-atmosphere heat flux, not to confuse the reader. “ocean heat flux” can easily be confused with horizontal fluxes of heat (see also line 10).

page 3775, line 15: “to assessment” should be “to assess”

page 3775, line 17: should refer to Fig. 1c.

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page 3778, line 19: reference should be (Raymo et al., 2006; Lee and Poulsen, 2009)

page 3779, line 19: correct to "..much smaller..."

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