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Reply on CC1

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Author comment on "Reduced-complexity model for the impact of anthropogenic CO_2 emissions on future glacial cycles" by Stefanie Talento and Andrey Ganopolski, Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-2-AC1, 2021

We are thankful to Mikhail Verbitsky for his comment. We agree that it is important to discuss the validity of the assumption that the Earth system’s future evolution will be similar to that observed during the past million years and we will address it in the revised version of our manuscript.

Before answering the question of why the model parameters were calibrated using the late and not the early Quaternary, it is important to stress that the paleoclimate records have been used to optimise the modelling of the natural (both past and future) evolution of the Earth system. The response to the anthropogenic forcing is a separate issue (see below). The choice of the late Quaternary records for model calibration was motivated by the Clark and Pollard “regolith hypothesis” about the nature of the mid-Pleistocene transition (MPT). According to this hypothesis, the MPT was caused by the gradual removal of a thick sediment layer from the northern part of the Northern Hemisphere continents by glacial erosion. Our recent experiments with the CLIMBER-2 model (Willeit et al., 2019) provide a strong support to this mechanism of the MPT. These results also demonstrate that this type of regime changes in the Earth system dynamics does not require variations of climate feedbacks. The rebuilding of the thick regolith layer even in the absence of new glaciations is a very slow process that will take many millions of years. As a consequence, it is reasonable to assume that the Earth system's natural evolution during the next million years will be similar to the evolution during the later Quaternary. Of course, it is possible that future glaciations will continue to change sediments distribution and, after some time, a new regime of variability different both from the late and early Quaternary will arise. However, such “no-analogue” problem cannot be addressed by using paleoclimate data or any other available information.

Regarding the Earth system future evolution after an anthropogenic perturbation, it is expected that it will deviate significantly from the natural evolution until the anthropogenic CO2 atmospheric concentration anomaly will be finally removed by weathering processes (Fig. 7 and 8 of the manuscript). This is explicitly accounted for in the model by including the effect of CO2 on the surface mass balance of ice sheets (Eq. 3). This aspect of the model cannot be validated using late Quaternary paleodata because during the last 800 kyr CO2 was never much higher than the preindustrial value. This is why, to constrain additional model parameters we used results of simulations with the CLIMBER-2 model (Ganopolski et al., 2016). Can early Quaternary paleoclimate records be useful for simple model calibration in addition to the late Quaternary and CLIMBER-2 results? We doubt that for two reasons. First, very different thickness of terrestrial sediments during the early Quaternary implies also very different ice sheet dynamics. Second, CO2 concentrations during the early Quaternary are extremely uncertain (at least +-50%).

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