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Modeling Greenland ice sheet evolution during the Plio-Pleistocene transition: new constraints for pCO_2 pathway

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During the late Miocene and early Pleistocene, first occurrences of Greenland ice sheet (GrIS) are documented. The late Pliocene intensification of Northern Hemisphere glaciation (NHG) with high-amplitude growth and decays of ice sheets have also been depicted through different observational studies. The last onset of a large GrIS occurred during MIS M2 (circa 3.3 Ma) but aborted after 50 ka. It is generally considered that the perennial glaciation of Greenland began around 2.7 Ma along with the intensification of NHG, indicated by records of ice rafted debris (IRD). Both data and coupled model studies have demonstrated that a decline in atmospheric pCO_2 levels was instrumental in establishing a perennial Greenland ice sheet (GrIS), yet models have generally used simplistic CO_2 constraints rather than those derived from data studies. In this contribution, thanks to the development of a new physically based forward modelling approach designed for coupling climate and cryosphere models over several 100-kyrs integrations, we simulate the Greenland ice sheet evolution during the Plio-Pleistocene Transition (PPT, 3.0-2.5 Ma). We demonstrate the pivotal role of specific CO_2 pathways, which are confined in a narrow window to trigger and maintain an extended GrIS: values lower than 280 ppmv are needed to produce the major extent of the GrIS at 2.7 Ma, whereas values higher than 320 ppmv, even with favourable insolation conditions, prevent the build-up of a large GrIS. Moreover, this forward method enables us to simulate the GrIS evolution with different pCO_2 scenarios derived from proxies and model reconstructions. When confronting simulated GrIS evolutions to IRD reconstructions, we find that some scenarios bear adequate consistency with the IRD records. Our study emphasizes the crucial role of the pCO_2 pathway for the GrIS evolution during PPT. Indeed, even evolving within a narrow window, pCO_2 reconstructed by different proxies lead to very different simulated GrIS evolutions. This large sensitivity to CO_2 pathways is particularly relevant in the context of GrIS response to future pCO_2 scenarios.