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A Gaussian process emulator for simulating ice sheet-climate interactions on a multi-million year timescale

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Fully coupled state-of-the-art Atmosphere-Ocean General Circulation Models are the best tool to investigate feedbacks between the different components of the climate system on a decadal to centennial timescale. On millennial to multi-millennial timescales, Earth System Models of Intermediate Complexity are used to explore the feedbacks in the climate system between the ice sheets, the atmosphere and the ocean. Those fully coupled models, even at coarser resolution, are computationally very expensive and other techniques have been proposed to simulate ice sheet-climate interactions on a million-year timescale. The asynchronous coupling technique proposes to run a climate model for a few decades and subsequently an ice sheet model for a few millennia. Another, more efficient method is the use of a matrix look-up table where climate model runs are performed for end-members and intermediate climatic states are linearly interpolated.

In this study, a novel coupling approach is presented where a Gaussian Process emulator applied to the climate model HadSM3 is coupled to the ice sheet model AISMPALEO. We have tested the sensitivity of the formulation of the ice sheet parameter and of the coupling time to the evolution of the ice sheet over time. Additionally, we used different lapse rate adjustments between the relatively coarse climate model and the much finer ice sheet model topography. It is shown that the ice sheet evolution over a million year timescale is strongly sensitive to the choice of the coupling time and to the implementation of the lapse rate adjustment. With the new coupling procedure, we provide a more realistic and computationally efficient framework for ice sheet-climate interactions on a multi-million year timescale.