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Exploring the complex uncertainties in coupled climate-ice simulations of the Last Glacial Maximum

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Simulating the co-evolution of climate and ice-sheets during the Quaternary is key to understanding some of the major abrupt changes in climate, ice and sea level. Indeed, events such as the Meltwater pulse 1a rapid sea level rise and Heinrich, Dansgaard–Oeschger and the 8.2 kyr climatic events all involve the interplay between ice sheets, the atmosphere and the ocean. Unfortunately, it is challenging to simulate the coupled Climate-Ice sheet system because small biases, errors or uncertainties in parts of the models are strongly amplified by the powerful interactions between the atmosphere and ice (e.g. ice-albedo and height-mass balance feedbacks). This leads to inaccurate or even unrealistic simulations of ice sheet extent and surface climate. To overcome this issue we need some methods to effectively explore the uncertainty in the complex Climate-Ice sheet system and reduce model biases. Here we present our approach to produce ensemble of coupled Climate-Ice sheet simulations of the Last Glacial maximum that explore the uncertainties in climate and ice sheet processes.

We use the FAMOUS-ICE earth system model, which comprises a coarse-resolution and fast general circulation model coupled to the Glimmer-CISM ice sheet model. We prescribe sea surface temperature and sea ice concentrations in order to control and reduce biases in polar climate, which strongly affect the surface mass balance and simulated extent of the northern hemisphere ice sheets. We develop and apply a method to reconstruct and sample a range of realistic sea surface temperature and sea-ice concentration spatio-temporal field. These are created by merging information from PMIP3/4 climate simulations and proxy-data for sea surface temperatures at the Last Glacial Maximum with Bayes linear analysis. We then use these to generate ensembles of FAMOUS-ice simulations of the Last Glacial maximum following the PMIP4 protocol, with the Greenland and North American ice sheets interactively simulated. In addition to exploring a range of sea surface conditions, we also vary key parameters that control the surface mass balance and flow of ice sheets. We thus produce ensembles of simulations that will later be used to emulate ice sheet surface mass balance.