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Towards a Bayesian calibration of the Glacial Systems Model of the Antarctic Ice Sheet over the last glacial cycle

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How much do past and present uncertainties of the Antarctic ice sheet (AIS) affect projections of its future evolution? Without the associated quantification of uncertainties, answers to these questions have little value. Glaciological modelling is an effective tool to generate continental-scale reconstructions over glacial cycles, but the models depend on parametrizations to account for the deficiencies (e.g., missing physics, unresolved sub-grid processes, uncertain boundary conditions) inherent in any numerical model. These parameters, considered together, form a parameter phase space from which sets of parameters can be sampled; each set corresponds to an ice sheet reconstruction. Are parametric uncertainties within glaciological models adequately represented so that a model can bracket reality? Here we study the evolution of the AIS over the last glacial cycle using the Glacial Systems Model (GSM) and apply a technique for explicit uncertainty quantification, a large-ensemble Bayesian calibration of models against large observational data-sets.

The GSM has been updated to suit this purpose with a number of recent developments: 1) hybrid ice physics; 2) Schoof grounding line parametrization; 3) hydrofracturing calving and ice cliff failure mechanisms; 4) sub-ice-shelf melt based on ocean temperatures; and 5) coupled glacial isostatic adjustment with a first order gravitational correction. Additionally, boundary conditions and ensemble parameters were included to account for uncertainties in the atmospheric and ocean forcing, basal drag and hydrology, basal topography, geothermal heat flux, and Earth viscosity structure.

This results in >36 ensemble parameters which define the parametric uncertainties within the GSM. Prior to conducting a full Bayesian calibration, one must first validate the ability of the GSM to simulate a broad range of responses. We attempt this by latin hypercube sampling of the parameter phase space and comparing the model predictions against our constraint database consisting of past elevation, extent and relative sea level observations and the present day geometry. We document the capability of the GSM to envelope the observational constraints given the parametric uncertainties and discuss interim calibration results for the evolution of the AIS.