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Glacial systems model calibration: Quantifying uncertainty in glaciological reconstructions of past ice-sheets

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What meaning does a glaciological reconstruction have without error bars? I would submit none. Interpretation of model results requires some combination of explicit and implicit uncertainty estimates. The glaciological, climate, and Earth systems modelling communities have been slow to incorporate, in any statistically self-consistent way, the objective determination of model and data uncertainties into their results. Though ensemble calculations offer a first step, the order million or more point sampling required to even partially cover glacial cycle model parametric uncertainties in the context of reconstructing past ice sheet chronologies precludes standard ensemble approaches.

I will present a Bayesian framework for model calibration based on a combination of Bayesian artificial neural networks and Markov Chain Monte Carlo (MCMC) sampling. The neural networks function as statistical emulators of model response to parameter variation. The calibration provides a posterior distribution for model parameters (and thereby in our case modelled glacial histories) given observational constraint data sets. This methodology explicitly accounts for constraint data uncertainty and emulation uncertainty of the neural networks along with a partial assessment of structural uncertainty of the model. The methodology also permits the incorporation of diverse and large sets of noisy constraint data into the calibration procedure and has been applied in varied incarnations to both General Circulation climate models and 3D glacial systems models (GSMs).

As partial validation, I will show that Bayesian artificial neural networks are effective and efficient emulators for GSM response, that they permit computationally feasible MCMC sampling of GSM ensemble parameters, and that therefore a full Bayesian calibration of a GSM is approachable (limited by incomplete assessment of structural uncertainty). To convey a concrete example, I will present relevant algorithmic details and some results from a recently completed calibration of a deglacial model for Eurasia. I will also summarize ongoing efforts towards more completely quantifying structural uncertainty, especially with respect to spatial-temporal correlations.