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Modelling the Laurentide Ice Sheet using improved ice margin chronologies and glacio-isostatic observations

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Creating models of the Laurentide ice sheet is challenging, due to the deficiency of chronological constraints and the uneven spatial resolution of data to determine the evolution of the glacio-isostatic response after deglaciation. Previous models relied on uncalibrated radiocarbon constrained margins that proved to have deficiencies in recent studies. Additionally, many recent Laurentide ice sheet models have been developed by incorporating climatic parameters that are poorly resolved for the late glacial period. We present a new ice sheet model by an iterative process of changing basal shear stress values and ice sheet margin location. A particular focus of this study is to determine the thickness and extent of the western Laurentide ice sheet, where there were few well dated observations of glacio-isostatic motion until recently.

The volume of an ice sheet during long periods depends mostly on basal shear stress and margin position, which are the main parameters that we vary to fit our model to glacio-isostatic observations. We build our ice model using the assumption of perfectly plastic, steady-state conditions, with variable basal shear stress. Basal shear stress values depend on the surficial geology underlying the ice, and are at a minimum in offshore regions that have soft, deformable sediments, and at a maximum in areas with exposed crystalline bedrock. This approach may not capture dynamic and short lived features of the ice sheet, such as ice streams and stagnant ice, but gives an approximation of average conditions to produce ice volumes that fit geophysical observations. We adjust the margin location when the shear stress conditions alone cannot account for the observed glacio-isostatic response. The constraints on the response include relative sea level benchmarks, sea level highstand positions and proglacial lakes. We repeat the analysis using different rheological profiles to determine the dependence the Earth model has on the estimation of ice sheet volume.

We develop our model of the Laurentide ice sheet using an updated margin evolution that spans the Wisconsin glaciation. We derive a margin history from calibrated radiocarbon, optical and cosmogenic data, with a specific focus on portraying the maximum possible extent of ice. Relative to previous reconstructions, the ice margin history of the Arctic has been dramatically altered. Ice margins extend to the edge of the continental shelves, and the retreat rate in continental regions has been delayed. Our modelled ice sheet remains near its maximum extent between 26 and 17 ka, as there are few chronological data that support ice free conditions over much of the area covered by it. The retreat of the western Laurentide ice sheet is slower than previous reconstructions, with the opening of the “ice-free corridor” between the Laurentide and Cordilleran ice sheets happening as late as 10.5 ka.