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Modelling the contribution of proglacial lakes to glacial isostatic adjustment and ice-sheet evolution

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Accurate knowledge of the evolution of the North American ice sheet during the last glacial cycle is important for interpreting climatological proxy data and determining the relationship between global climate and sea-level on the millennial to multi-millennial time-scale. Current estimates of the shape and volume of the ice sheet depend on geomorphological evidence, observations of ongoing crustal relaxation and numerical ice-sheet models. However, both the ice-sheet evolution and the resulting crustal deformation were influenced by the presence of vast proglacial lakes during the deglaciation. The presence of such large bodies of water could have resulted in the formation of floating ice shelves, possibly leading to an acceleration of mass loss through basal melt and calving, and would have reinforced the crustal deformation caused by the ice sheet itself. Neglecting these effects might lead to inaccuracies in the interpretation of observed of crustal motion and the resulting reconstructed ice-sheet evolution.
We have created a model set-up consisting of a numerical 3-D ice-sheet-shelf model coupled to a Maxwell viscoelastic solid Earth model, which accounts for the presence of proglacial lakes. We show that the mass of the lakes has a relatively small effect on crustal deformation and the geoid. The effect on the evolution of the ice-sheet is shown to be strong. The formation of lacustrine ice shelves leads to a strongly accelerated retreat of the ice, particularly over the present-day Hudson Strait area, where the underlying bedrock has a negative slope relative to the ice flow direction – similar to the Marine Ice Shelf Instability proposed in literature. This process results in the drainage of the lake through the Hudson Strait and the splitting up of the ice sheet into two separate domes, both in agreement with geomorphological evidence.