Ice Sheet Sensitivity to Basal Processes in Idealized North American Glacial Cycles

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Summary

Ice sheet basal processes (e.g. sliding and sedimentary) are dictated by substrate coupling (Cuffey and Paterson, 2010). This coupling is thought to be modulated by subglacial hydrology – increased water pressure at the base decreases the coupling (Alley, 1989). To date, however the effect of subglacial hydrology is poorly tested in continental scale ice sheet models: we probe how inclusion of a hydrology model contributes to basal motion. Traditionally, the connection between glaciological ice sheet modelling and glacial geology has been somewhat convoluted. With the recent development of physically based sediment production and transport laws (*e.g*. Hallet (1996), Iverson (2010), and Iverson (2012)) and application of these laws in numerical models (*e.g*. Hildes et al. (2004) and Melanson, Bell, and Tarasov (2013)), we can begin to tie glacial geology more closely to paleo ice sheet modelling. This is an opportunity to incorporate new geologic constraints into models of Pleistocene glacial cycles. Here we present coupling of recent state of the art sediment and hydrology models in a continental scale glacial systems model for an idealized North American setup.

Model

Currently there are few ice sheet models which implement sediment production and transport. There are fewer still with a realistic hydrology which modulates these sedimentary processes. To date, models of subglacial hydrology have been designed for either glacier scale (complex description of processes, *e.g*. Werder et al. (2013)) or continental scale (heavily simplified for basal drag calculation, *e.g*. Budd and Warner (1996)). Additionally, these models have assumed either flow through a poroelastic medium (i.e. unconsolidated regolith (Flowers and Clarke, 2002)) or a linked-cavity system (a network of cavities which open up in the lee side of bed-highs, linking in a drainage network (Walder and Hallet, 1979)). A subset of these models also include rapid drainage in subglacial tunnel networks which open when system throughput is high (de Fleurian et al., 2018). The model presented here represents a trade off: a parameterized choice of poroelastic and linked-cavity systems for inefficient drainage with a flux switch to efficient (tunnel) drainage (*e.g*. the flux switch of Schoof (2010)). The subglacial sediment model incorporates both abrasion and quarrying with transport via both glacial entrainment and soft sediment deformation (Melanson, Bell, and Tarasov, 2013).

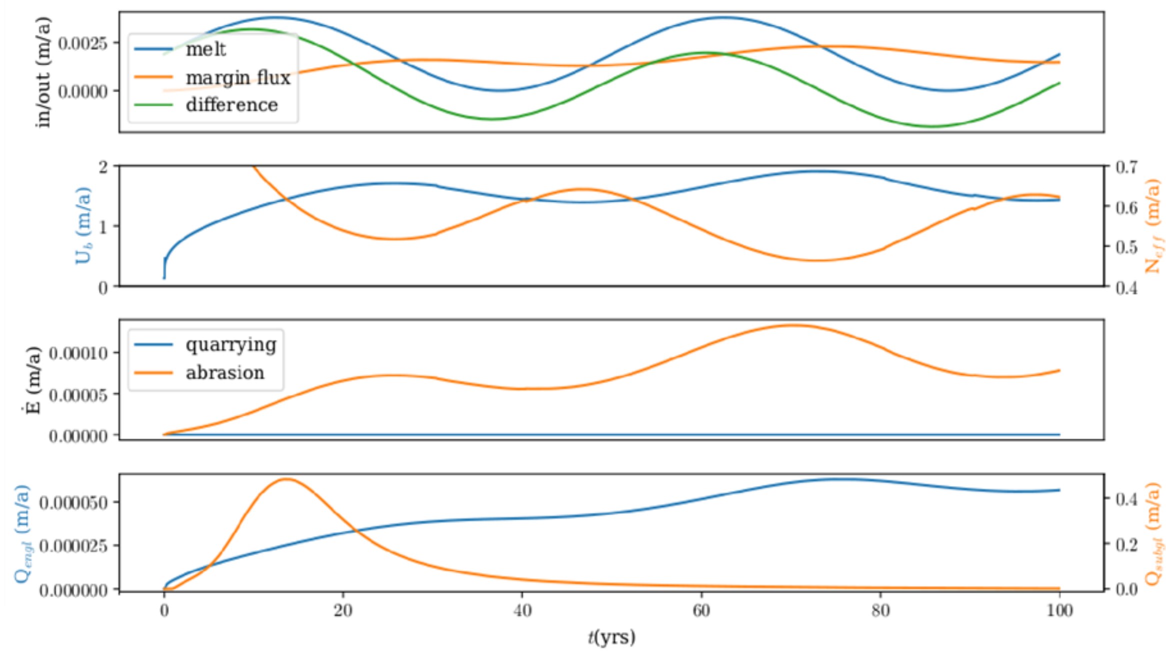

Figure 1: Output of the coupled system for a single parameterization. Prescribed basal melt is sinusoidal and the resulting changes in effective pressure (*i.e.*, basal coupling), N_{eff}, give speed up and slow down of basal velocity, U_b. Both effective pressure and basal velocity drive the erosion rates, $\dot{E}$, as well as the englacial, Q_{engl} and subglacial Q_{subgl} transport rates. Measures normalized by ice sheet areal extent.

These sediment and hydrology models have been fully coupled to the Glacial Systems Model (GSM, Tarasov et al. (2012)), a 3D ice sheet model with full suite of ice dynamics, solid earth processes, and range of climate representations constrained with a range of geophysical and geological data. These models have passed verification for symmetry, convergence with temporal and spatial resolution, mass conservation, and reproduction of solutions from similar but more complex models. Simple setups are useful for testing expected system behaviours and enable simulating large ensembles for comparing varied input parameters with model solutions. Our probe will examine a large ensemble of glacial cycle model runs for sensitivity of surge events and erosion rates in an idealized North American setup.

Conclusions

Here we present subglacial hydrology and sediment models fully coupled to the GSM. This allows the modelling of glacial sediment production and transport at glacial cycle and continental scales and is an opportunity to incorporate geologic constraint to Pleistocene ice sheet models. Finally, we test the comparative effect of inclusion and form of subglacial drainage systems on ice sheet dynamics for an idealized North America, looking in particular at southern margin surge lobes and erosion rates.

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