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A semi-analytical model for marine ice sheet dynamics

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Marine ice sheets have the greatest potential to contribute to rapid sea-level change because of the potential for rapid transfer of grounded ice (with thickness above flotation) to floating ice shelves or icebergs. Ice loss occurs when this transfer (the 'grounding-line flux') is larger than the rate at which ice accumulates over the grounded ice sheet. It is well known that the balance between accumulation and grounding-line flux can result in both stable and unstable ice-sheet states, and that this leads to the potential for 'marine-ice-sheet-instability' (MISI). Various reduced mathematical models have been used to examine the stability of steady states, accounting for different parameterisations of basal drag, lateral buttressing and ice-shelf melting/calving. However, real-world ice sheets are (presumably) rarely in a steady state, since the timescales taken for an ice-sheet to reach steady state are typically thousands of years, longer than the timescales on which the forcing changes. The time-dependent dynamics are therefore important.

Here, we detail a simple depth- and width- integrated model for a marine ice sheet that yields insight into the time-dependent dynamics that result from changing climate forcing. The model - which reduces to a relatively simple dynamical system - demonstrates how gradual changes in forcing (surface accumulation, ocean temperature, for example) cause changes in the 'landscape' through which the ice-sheet evolves. It reproduces some existing results for how the stability of steady states depends on the topography, as well as new results for the pace of groundling advance and retreat. Investigating fundamental aspects of the time-dependent dynamics in a simplified model like this is important in order to understand the extent to which ice-sheet changes are 'irreversible' (or not).