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Grounding line retreat induced by stochastic forcing of marine-terminating glaciers

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Marine-terminating glaciers are subject to stochastic variations in many processes, including snowfall, ocean melting and calving. However, state-of-the-art ice sheet models typically do not include noise in key environmental parameters, under the assumption that glaciers integrate noise, resulting in the same time-averaged state which would occur in the absence of stochastic forcing. In this study, we re-examine this assumption by considering how the time-averaged state of a marine-terminating outlet glacier may be modified by the inclusion of symmetrically-distributed noise in environmental and ice sheet processes.

We begin by showing that a simple mathematical model can accurately reproduce time-dependent variations in grounding line position as simulated in a fully-resolved marine-terminating glacier model. We show how this simple model can be used to make analytical predictions about the characteristic glacier response time to forcing, and the autocorrelation function expected from stochastic variations in accumulation, ice shelf melting by the ocean and calving. Stochastic forcing can cause an otherwise stable grounding line to rapidly retreat over regions of retrograde bed slope. The predictability of such a noise-induced retreat is shown to depend on the local curvature of bed topography. We also show that even in the absence of retrograde slopes, symmetric stochastic forcing can cause retreat of the time-averaged grounding line position, due to nonlinearity in key ice sheet processes. We conclude by arguing why stochastic forcing should be included in ice sheet models and how to use these tools to aid in the interpretation of observations.