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Representation of calving in ice sheet models

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Calving losses form a major component of ablation from the Greenland and Antarctic Ice Sheets and innumerable other glaciers and ice caps worldwide. The same was true for the great Pleistocene ice sheets. Calving, however, is very poorly represented in current ice sheet models, severely limiting realistic simulation of the growth and retreat of water-terminating ice sheets and glaciers. Existing 'calving laws' are not derived from physical principles, but rely on empirical correlations based on limited datasets. A new calving criterion is introduced, which predicts calving where the depth of surface crevasses equals ice height above sea level. Crevasse depth is calculated from strain rates, and terminus position and calving rate are therefore functions of ice velocity, strain rate, ice thickness and water depth. We couple the calving criterion with a new 'sliding law', in which velocity is controlled by a combination of basal and lateral drag. Model runs indicate that calving glaciers are likely to undergo flow acceleration and rapid terminus retreat in response to imposed thickness changes if basal drag provides most resistance to flow, but not if most resistance is from lateral drag. The model can be used to simulate much of the observed spectrum of behaviour of calving glaciers, and presents new opportunities to model ice sheet response to climate change.