Granular model of ice explains diverse calving patterns from grounded and floating glaciers

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Iceberg calving has been implicated in the recent retreat and acceleration of glaciers, ice tongues and ice shelves along the Greenland and Antarctic ice sheets. Calving, however, is a complex process that is difficult to directly observe much less simulate. Despite the paucity of data, satellite imagery and time lapse photography reveal that individual calving events manifest an incredible diversity in calving patterns, including the detachment of large tabular bergs from floating ice tongues, the disintegration of ice shelves and the capsizing of smaller bergs from grounded glaciers terminating in deep water. Here we present a numerical model that succeeds in mimicking these disparate calving regimes. Our model departs from traditional viscous representations of ice and caricatures glacier ice as a granular material made of interacting boulders of ice that are bonded together. This discretization focuses on the short-term elastic behavior of glaciers providing us with the ability to "resolve" individual iceberg calving events. Our simulations reveal that different calving regimes are controlled to first order by glacier geometry and that calving is a three-part process that involves ice fracture, the advection of crevasses and the transport of detached icebergs away from the calving front. Our model also suggests the potential for catastrophic ice mass disintegration in regions where highly crevassed glaciers are grounded deep beneath sea level.