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Universal Dynamic Calving Law implies Potential for Abrupt Ice-Shelf Retreat

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Recently observed large-scale disintegration of Antarctic ice shelves has moved their fronts closer towards grounded ice. In response, ice-sheet discharge into the ocean has accelerated, contributing to global sea-level rise and emphasizing the importance of calving-front dynamics. The position of the ice front strongly influences the stress field within the entire sheet-shelf-system and thereby the mass flow across the grounding line. While theories for an advance of the ice-front are readily available, no general rule exists for its retreat, making the study of ice-front motion inaccessible. Here we present a universal dynamic calving law which (1) combines observations into a mathematically simple first-order relation, (2) depends only on local ice-flow properties, (3) naturally incorporates the stabilizing effect of pinning points and (4) inhibits shelf-ice growth outside of embayments. In numerical simulations it reproduces multiple stable fronts as observed for the Larsen A and B Ice Shelves including rapid transitions between them caused by localized ice weaknesses. We also observe an abrupt retreat of Ross Ice Shelf at the gateway of the West Antarctic Ice Sheet which reduces back stresses onto the sheet by up to 40%. Our results thus enable the study of ice-front motion and have strong implications for global sea level rise.