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Marine Ice-cliff instability: How Does it Work, and What Controls Ice Retreat Rates?

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Marine Ice Cliff Instability (MICI) has been proposed as a mechanism through which marine-based ice sheets could undergo rapid collapse and mass loss. MICI is based on the idea that the finite strength of ice places a limit on ice cliff height above sea level (freeboard); therefore, if buttressing ice shelves disintegrate and expose deep calving cliffs, widespread catastrophic ice-sheet disintegration could occur. Ice sheet models incorporating MICI processes predict rapid disintegration of the Amundsen Sea sector of the West Antarctic Ice Sheet under high CO_2 scenarios (Pollard et al., 2015; DeConto and Pollard, 2016). These models, however, employ highly simplified parameterizations of key calving processes, and possible rates of future ice loss and sea level rise remain subject to large uncertainties. MICI invokes ice-front behaviors beyond the current observed range, complicating attempts to validate model results.

DOMINOS (Disintegration of Marine Ice Sheets: Novel Optimized Simulations; part of the International Thwaites Glacier Collaboration) aims to develop detailed process-based models of MICI and its impact on the sensitivity of the West Antarctic Ice Sheet. Here we present preliminary results from the Helsinki Discrete Element Model (HiDEM), which aim to understand the mechanics of ice-cliff instability and determine the spatial and temporal scales of failure events. Collapse of deep ice cliffs (>90 m freeboard) occurs in response to temporally varying longitudinal and buoyant forces, and involves complex mixed-mode rheology including brittle failure, viscous deformation, and enhanced viscous flow along shear zones. Calved bergs form floating tongues of mélange, which may provide stabilizing backstress if jamming occurs against lateral or basal pinning points. In the absence of backstress, mechanical instability propagates upglacier, causing rapid, unstable retreat where basins deepen inland.