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Glacial cycle ice-sheet evolution controlled by ocean bed properties

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Shortcomings in the description of ice dynamics have been recognized as a major limitation for projecting the evolution of the Greenland and Antarctic ice sheets. If current sea-level rise rates continue unabated, up to 630 million people will be at annual flood risk by 2100; making improved ice-sheet model projections a priority and of high socio-economic impact. Since the boundary condition at the underside of the ice-sheet is poorly known, improving constraints on the basal ice/bed properties is essential for accurate prediction of ice-sheet stability and grounding line positions. Furthermore, the history of grounding-line positions since the Last Glacial Maximum has proven challenging to understand due to uncertainties in bed conditions. Here we use a 3D full-Stokes ice-sheet model to investigate the effect of differing ocean bed properties on ice-sheet advance and retreat over a glacial cycle of 40,000 years. We do this for the Ekström Ice Shelf catchment, East Antarctica. We find that predicted ice volumes differ by >50 % under almost equal forcing when comparing (low-friction) sediment-covered with (high-friction) crystalline ocean beds. Grounding-line positions differ by >100 % (49 km), show significant hysteresis, and migrate non-steadily in both scenarios with long quiescent phases disrupted by leaps of rapid migration. Our new modelling framework extends the applicability of 3D full-Stokes ice-sheet models by an order of magnitude to previous studies. The simulations predict evolution of two entirely different catchment geometries (namely thick and slow vs. thin and fast), triggered exclusively by variable ocean-bed properties. This highlights that constraints not only for the bathymetry but also its geological properties are urgently needed for predicting ice-sheet evolution and sea level change.