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Future projections of Greenland's ice loss accounting for changes in surface mass balance and dynamic discharge

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Under future climate change, the Greenland Ice Sheet (GrIS) is highly vulnerable as its margins are relatively warm compared to Antarctica making them relatively prone for summer melting. A rise of about three degrees in annual average temperature over Greenland is expected to lead to irreversible ice sheet melting, which makes the GrIS a sensitive element in the Earth's climate system. Moreover, extended coverage and improved observation techniques have revealed high variations in dynamical ice discharge from outlet glaciers around the entire ice sheet. During the last decade, this dynamic discharge has contributed to almost half of the total mass loss. Since variations of the dynamic discharge are limited to the GrIS margin, direct inland transmission of these perturbations is necessary to significantly alter the overall GIS evolution on short time scales. Gradients in membrane stresses hold the potential for direct horizontal coupling and thus concerns are raised whether direct signal transmission has a significant impact on the ice interior. Because of strong mutual feedbacks between surface mass balance and marginal ice dynamics, our aim is to account for changes in both to assess the future GrIS contribution to sea level rise.

For this purpose, we use a three-dimensional ice sheet model with a Blatter/Pattyn dynamic core that allows for direct signal transmission in ice flow. The surface mass balance is calculated by a positive degree-day model, which accounts for internal accumulation and temporary water storage in the snow cover. The model is initialised by calibrating a glacial cycle spin-up to the present day geometry. For the last half of the 20th century we force the ice sheet model with reanalysis data of surface temperature and precipitation. Future climate scenarios are taken from general circulation models and used in anomaly mode in the positive degree-day model. These scenarios are based on the representative concentration pathways that were suggested for the fifth assessment report by the International Panel on Climate Change. For the dynamic response of the ice sheet, we link the ice discharge of all marine terminated outlet glaciers to the atmospheric temperature signal induced by each scenario. We use a horizontal model resolution of 5 km for these experiments in order to capture observed details in the GrIS' velocity field such as the artery-like streams or marine terminated outlet glaciers.