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Modelling the impacts of ice damage on the response of Thwaites Glacier, West Antarctica

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Ice shelves around the coastal portion of the Antarctic ice sheet are sensitive indicators of climate change. The thinning of ice shelves diminishes buttressing, promotes longitudinal spreading, and increases ice flux across the grounding line, leading to accelerated glacier discharge into the ocean. Thwaites Glacier in the Amundsen Sea Embayment is one of the fastest-changing outlet glaciers in Antarctica. Damaged areas with densely distributed crevasses and open fractures on Thwaites Glacier are key to future ice shelf stability, grounding line retreat and sea level contribution. The damage feedback processes should be taken into consideration when simulating the evolution of Thwaites Glacier using ice sheet models.

Here, we add the continuum damage mechanics approach to the F.ETISh/Kori ice flow model, to simulate the present-day and near future behavior of the ice sheet and ice shelf system, including brittle ice physics. The damage field is described by equating it to the total crevasse depths used in Nick et al. (2010) and Sun et al. (2017). 100 years simulations under present-day climate conditions with and without damage in different scenarios have been conducted, and the change in ice velocity, ice thickness, the grounding line retreat and the sea level contribution of Thwaites Glacier have been analysed. Moreover, the change in ice velocity along four ice flow profiles in the first 20-year simulation has been analysed and the impact of damage on velocity has been assessed by comparing the simulated velocity fields with the observations (e.g., the MEaSUREs and ITS_LIVE ice velocity products).

Results indicate that damage drastically increases the ice velocity over the ice shelves and weakens them as such that grounding line retreat ~18 km after 20 years, accelerates (~1.5 times) compared to the observed increase in flow speed and contributes around an order of magnitude to the sea level rise in 50 years. Change in ice velocity profiles of Thwaites Glacier also show that local damage may overestimate ice velocity, especially in the grounded ice near the grounding line, while it underestimates observed ice flow when local damage is omitted. Through a series of further sensitivity experiments, an analysis on the timing and magnitude of damage has been carried out to gauge the current and near future state of the Thwaites glacier basin.