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Advances in modeling the response of Greenland marine terminating glaciers to enhanced ocean forcing

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The Greenland ice sheet has been losing mass in response to the rapid warming of the Arctic, and is contributing to sea level rise at an increasing rate. Fluctuations in ocean and atmosphere circulations are not only affecting the amount of melting and runoff at the ice sheet surface, they also produce acceleration, thinning and retreat of multiple outlet glaciers around Greenland. Numerical models are the best tools to assess the vulnerability of the Greenland ice sheet to climate warming and to make projections of the future of the ice sheet under different scenarios of CO_2 emissions. Yet, predicting how fast the ice sheet will be melting has proven to be challenging, primarily because of (1) the poor knowledge of the bed topography and bathymetry in the vicinity of the ice sheet margin and (2) our limited understanding of calving dynamics. Bed topography is indeed a fundamental control on ice dynamics and ocean circulation along Greenland's periphery, while calving dynamics controls the rate of retreat of marine terminating glaciers.

We first present recent advances made in mapping the bed topography and ocean bathymetry around the periphery of the ice sheet. By assimilating seafloor bathymetry and ice thickness data through a mass conservation approach, we produced a new 150-m resolution bed topography/bathymetric map of Greenland with seamless transitions at the ice/ocean interface: BedMachine v3. We then show how this new dataset helps in turn improve our ability to model ice front dynamics. We focus on modeling the response of Northwest Greenland (from 72.5°N to 76°N) to ocean forcing. Warm and salty Atlantic water, which is typically found at a depth below 200-300 m, has the potential to trigger ice-front retreats of marine-terminating glaciers, and the corresponding loss in resistive stress leads to glacier acceleration and thinning. It remains unclear, however, which glaciers are currently stable but may retreat in the future, and how far inland and how fast they will retreat. We rely on the ice melt parameterization from Rignot et al. 2016, and use ocean temperature and salinity from high-resolution ECCO 2 simulations on the continental shelf to constrain the thermal forcing. The ice flow model includes a calving law based on a Von Mises criterion. We investigate the sensitivity of Northwest Greenland to enhanced ocean thermal forcing and subglacial discharge. We find that some glaciers, such as Dietrichson Gletscher or Alison Gletscher, are sensitive to small increases in ocean thermal forcing, while others, such as Illullip Sermia or Qeqertarsuup Sermia, are very difficult to destabilize, even with a quadrupling of the melt. Under the most intense melt experiment, we find that Hayes Gletscher retreats by more than 50 km inland into a deep trough and its velocity increases by a factor of 10 over only 15 years. The model confirms that ice-ocean interactions are the triggering mechanism of glacier retreat, but the bed controls its magnitude.