Modeling the flow dynamics of Bowdoin Glacier, Qaanaaq region, northwestern Greenland

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The Qaanaaq drainage basin, situated in the northwestern part of the Greenland ice sheet, is a typical Greenlandic drainage basin that consists of an inland accumulation area and a marginal ablation area with a number of fast-flowing outlet glaciers. It is still relatively unexplored, and was therefore the focus of field and remote sensing activities (ice thickness, mass balance, surface velocity etc.) in Greenland, conducted within the Green Network of Excellence (GRENE) Arctic Climate Change Research Project (www.nipr.ac.jp/grene).

Located 30 km northeast of Qaanaaq, Bowdoin Glacier (77º41' N, 68º35' W) is a fjord-terminating glacier which was intensively surveyed in the GRENE field campaigns in summer 2013, 2014 and 2015. Here we present the modeling of Bowdoin Glacier dynamics with the full Stokes model Elmer/Ice (http://elmerice.elmerfem.org). Using the available data set for the basal and surface topographies (Bamber and others, 2013, and own, still unpublished data for the Qaanaaq region), a high-resolution footprint of the glacier is created and vertically extruded using 11 terrain-following layers to form the three-dimensional finite element mesh. The flow model is coupled with a temperature field which is computed by a one-dimensional formulation of the energy equation that assumes melting conditions on the entire glacier base. The numerical solutions are then obtained by using a direct solver coupled with stabilization procedures.

We first carry out an inversion procedure to compute the present-day distribution of the basal drag coefficient. The control inverse method employs the observed surface velocities (Sugiyama and others, 2015) to compute the basal drag coefficient by minimizing the misfit between the surface velocities computed with the model and the observed velocities. The computed basal drag coefficient is then used for the sensitivity experiments carried out to simulate the glacier sensitivity to external forcings. More specifically, we aim at understanding and explaining the observed present-day flow pattern of Bowdoin Glacier, and we investigate with the model the observed glacier sensitivity to basal perturbations (lower basal drag coefficient due to the drainage of surface water towards the bedrock) and to sea tide. We find that perturbations at the glacier bed produce a significant acceleration of the glacier even with a moderate decrease of the basal drag coefficient by 10%. When lowering the sea level, hence changing the hydrostatic pressure exerted at the glacier front, the glacier also depicts a significant speed-up whereas with high tides, the glacier flow velocity is smaller. We analyze the computed stress regime driving the ice deformation at the glacier, and we elucidate the influence of sea tide on the glacier flow.

References

Bamber J.L. and 10 others (2013): A new bed elevation dataset for Greenland. The Cryosphere, 7, 499-510.
Sugiyama S, Sakakibara D, Tsutaki S, Maruyama M and Sawagaki T (2015): Glacier dynamics near the calving front of Bowdoin Glacier, northwestern Greenland. J. Glaciol., 61(226), 223–232.