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Application of a higher-order flow model to Greenland outlet glacier dynamics

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We introduce a straightforward procedure for tuning modeled ice sheet velocities to a target velocity field and geometry and apply the method to modern-day observations (balance velocities and geometry) from the Greenland ice sheet (GIS). The result is a steady-state, initial condition for a three dimensional, higher-order ice flow model of the GIS. The route mean-square difference between the modeled and target velocity fields is $\sim$38 m/yr for the entire ice sheet and $\sim$5 m/yr for individual drainage basins of interest. We use this initial condition in perturbation experiments for Jakobshavn, Helheim and Kangerdlugssuaq glaciers, for which we adjust the stress boundary condition at the outlet glacier termini in order to match modeled and observed flux changes over the past decade. Remote-sensing observations over the past decade confirm that the model experiments capture the large-scale, observed patterns of ice sheet thinning. By stepping the model forward in time and integrating geometry changes in time and space, we estimate that these three outlet glaciers will contribute at least $\sim$0.3 and $\sim$1 mm to sea-level rise (SLR) over the next decade and century, respectively. Moreover, we find that the long-term, diffusive component of ice sheet thinning is responsible for a minimum of 3/4 of the total SLR contribution from these basins over the next $\sim$100 years. Thus, a significant future SLR contribution already exists within the GIS as a result of perturbations to outlet glacier systems that took place during the past decade.