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A two-step mass-conservation approach to infer ice thickness maps: Performance for different glacier types on Svalbard

Johannes J. Fürst (1), Thorsten Seehaus (1), Björn Sass (1), Kjetil Aas (2), Toby J. Benham (3), Julian Dowdeswell (3), Xavier Fettweis (4), Fabien Gillet-Chaulet (5,6), Geir Moholdt (7), Francisco Navarro (8), Christopher Nuth (2), Rickard Petterson (9), and Matthias Braun (1)

(1) University of Erlangen-Nuremberg, Erlangen, Germany, (2) University of Oslo, Oslo, Norway, (3) Scott Polar Research Institute, Cambridge, England, (4) University of Liège, Liège, Belgium, (5) Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France, (6) Université Grenoble Alpes, Grenoble, France, (7) Norwegian Polar Institute, Tromsø, Norway, (8) Universidad Politécnica de Madrid, Madrid, Spain, (9) Uppsala University, Uppsala, Sweden

Satellite remote sensing based on optical or radar instruments has enable us to measure glacier-wide surface velocities as well as changes both in glacier extent and in surface elevation with good coverage worldwide. Yet, for the large majority of all glaciers and ice caps, there is in fact no information on how thick the ice cover is. Any attempt to predict glacier demise under climatic warming and to estimate the future contribution to sea-level rise is limited as long as the glacier thickness is not well constrained. Moreover, the poor knowledge of the bed topography inhibits the applicability of ice-flow models which could help to understand dominant processes controlling the ice-front evolution of marine-terminating glaciers. The reason is that the basal topography exerts major control on the dynamic response of grounded ice. As it is impractical to measure ice thicknesses on most glaciers, reconstruction approaches have been forwarded that can infer thickness fields from available geometric, climatic and ice-flow information. Here, we presented a two-step, mass-conserving reconstruction approach to infer 2D ice-thickness fields with prior knowledge on source and sink terms in the mass budget.

The first-step reconstruction is aimed at glaciers for which not much information is available. Input requirements for this first step are comparable to other reconstruction approaches that have successfully been applied to glaciers world-wide. In fast-flowing areas where surface velocity measurements are most reliable, these observations enter a second-step reconstruction providing an improved thickness estimate. In both steps, available thickness measurements are readily assimilated to constrain the reconstruction. The approach is tested on different glacier geometries on Svalbard were an abundant thickness record was available. On these test geometries, we show that the approach performs well for entire ice caps as well as for marine- and land-terminating glaciers. The reconstructed thickness field is provided together with an error-estimate map which stems from a formal propagation of input uncertainties through the underlying equations.