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Estimating large scale dynamic mountain glacier states with numerical modelling and data assimilation

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Ongoing global glacier retreat leads to sea-level rise and changes in regional freshwater availability. For an adequate adaptation to these changes, knowledge about the ice volume and the current dynamic state of glaciers is crucial. At regional to global scales, sparse observations made the dynamic state of glaciers very difficult to assess. Thanks to recent advances in global geodetic mass-balance and velocity assessments, new ways to initialize numerical models and ice thickness estimation emerge. In this contribution, we present the COst Minimization Bed INvErsion model (COMBINE), which aims to be a cheap, flexible global data assimilation and inversion method. COMBINE uses an existing numerical model of glacier evolution (the Open Global Glacier Model, OGGM) rewritten in the machine learning framework PyTorch. This makes the model fully differentiable and allows to iteratively minimize a cost function penalizing mismatch to observations. Thanks to the flexible nature of automatic differentiation, various observational sources distributed in time can be considered (e.g. surface elevation and area changes, ice velocities). No assumption about the dynamic glacier state is needed, releasing the equilibrium assumption often required for large scale ice volume computations. In this contribution, we will demonstrate the capabilities of COMBINE in several idealized and real-world applications, and discuss its added value and upcoming challenges for operational application.