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3-D Higher-Order modelling of Vadret da Morteratsch (Switzerland): past extent, present-day dynamics and future evolution

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A three-dimensional glacier flow model was developed for the Vadret da Morteratsch, Engadin, Switzerland, in order to better understand the strong retreat of the glacier since the end of the Little Ice Age (LIA) and to project its further retreat under an intensifying warming trend. The ice dynamics model is a state-of-the-art higher-order model implemented on a 25 m horizontal resolution and considers both ice deformation and basal sliding. It is coupled to a two-dimensional energy balance model forced by monthly temperature and precipitation data. Both models make use of a comprehensive dataset collected over the past decade that includes ice thickness, surface mass balance and surface velocity measurements. The ice thickness and bedrock topography are derived from a series of ground-penetrating radar (GPR) transects which are inter- and extrapolated over the entire glacier using the plastic flow assumption for central regions and an inverse quadratic distance interpolation to obtain U-shaped cross-sections.

The observed present-day velocity field can be closely reproduced (RMSE around 15 m a-1), by simultaneous tuning of the rate factor of Glen's flow law and the proportionality factor in a Weertman-type of sliding law. Basic steady state experiments show that if present-day climate persists, the tongue of the glacier retreats by more than 1 km, while the Morteratsch glacier disconnects from and its main tributary, the Pers glacier. Based on length and volume preservation experiments, a temperature forcing of between -1°C and -2°C with respect to 2000-2010 is required to maintain the glacier in its actual shape.

For assessing the fast retreat since the LIA, transient simulations of the glacier evolution are performed based on precipitation and temperature series from nearby meteorological stations. For the future a series of climatic scenarios are adopted. Past glacier extents, which are well known from field evidence and historical data, are used as an additional calibration tool for the flow and mass balance model. Assuming more than 3-4°C of warming by 2100, only isolated ice patches remain at high elevation. These are largely stagnant and precede the almost total demise of the Morteratsch glacier complex if those climate conditions were sustained beyond that period.