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On the climate-geometry imbalance of Vadret da Morteratsch (Switzerland) and its response time: insights from numerical 3-D flow simulations

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When a glacier is subject to a change in mass balance it needs a certain amount of time to adjust its length and volume. In the literature the response time is referred to as the time a glacier takes to complete most of its adjustment to a change in mass balance, but such a broad definition is not always satisfactory. A better insight in the response time of glaciers and the main controlling factors is however crucial to improve future projections, as the evolution of glaciers in the coming decades is largely determined by their past evolution and present-day imbalance.

Here we investigate the climate-geometry imbalance and the response time of Vadret da Morteratsch (Engadine, Switzerland) by using a 3-D higher-order ice flow model. In earlier studies the glacier flow model was calibrated with observed surface velocities, and used to simulate the glacier evolution since 1865 driven by a 2-D energy surface mass balance model. This modelling relies on an extensive observational dataset collected on the glacier over the last 13 years.

The present-day imbalance between glacier geometry and climate is analysed by performing steady state simulations. We investigate the retreat under present-day climate and the forcing needed to maintain the present-day glacier length and volume. Subsequently we do this for the previous decades to understand how the climate-geometry imbalance changed over time.

In our analysis of response times, we impose idealized step changes in mass balance and quantify the time needed to reach a new equilibrium. We analyse the factors that influence the length and volume response time, such as glacier size, glacier thickness (flow parameters), the magnitude and spatial distribution of the mass balance forcing and the differences occurring between glacier advance and retreat. Subsequently, we compare our results with simpler analytical approaches from the literature and discuss the applicability of each method to characterize the response time of Vadret da Morteratsch.