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On the climate-geometry imbalance, response time and volume-area scaling of an alpine glacier: insights from a 3-D flow model applied to Vadret da Morteratsch

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The worldwide mass loss of glaciers in the coming century will not only result from additional warming, but will also be a consequence of the glacier's response to the 20th century warming. This is a consequence of their response time, as a change in mass balance needs time to translate into a change in glacier geometry. A better insight in the response time of glaciers is therefore crucial to improve future glacier projections. Our knowledge on glacier response times mainly relies on analytical methods, conceptual models and numerical experiments with idealized glacier setups. Here we present for the first time a detailed 3-D ice flow modelling study on the response time of an individual glacier. The modelling relies on an extensive observational dataset and on ice flow and mass balance models that are calibrated and validated against different sources. This unique setup allows us to analyse the response time of an alpine glacier in a realistic setting and look at the different factors that influence it, with a particular focus on those not taken into account in analytical methods and conceptual models.

We start by analysing the present-day and past climate-geometry imbalance. Subsequently we focus on the response time and the effect of the magnitude and spatial distribution of the forcing, which effects have hitherto not been investigated. Response times from our numerical simulation are compared with analytical methods and also the influence of the glacier size is examined. Finally we discuss the applicability of the volume-area scaling, suggest how the glacier slope can be incorporated, and analyse the impact of the climate-geometry imbalance on this relationship.