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Modelled non-linear response to climate of Hardangerjøkulen ice cap, southern Norway, since the mid-Holocene

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Glacier and ice cap volume changes currently amount to half of the total cryospheric contribution to sea-level rise and are projected to remain substantial throughout the 21st century. To simulate glacier behavior on centennial and longer time scales, models rely on simplified dynamics and tunable parameters for processes not well understood. Model calibration is often done using present-day observations, even though the relationship between parameters and parametrized processes may be altered for significantly different glacier states.

In this study, we simulate the Hardangerjøkulen ice cap in southern Norway since the mid-Holocene, through the Little Ice Age (LIA) and into the future. We run an ensemble for both calibration and transient experiments, using a two-dimensional ice flow model with mesh refinement. For the Holocene, we apply a simple mass balance forcing based on climate reconstructions. For the LIA until 1962, we use geomorphological evidence and measured outlet glacier positions to find a mass balance history, while we use direct mass balance measurements from 1963 until today.

Given a linear climate forcing, we show that Hardangerøkulen grew from ice-free conditions in the mid-Holocene, to its maximum LIA extent in a highly non-linear fashion. We relate this to local bed topography and demonstrate that volume and area of some but not all outlet glaciers, as well as the entire ice cap, become decoupled for several centuries during our simulation of the late Holocene, before co-varying approaching the LIA.

Our model is able to simulate most recorded ice cap and outlet glacier changes from the LIA until today. We show that present-day Hardangerøkulen is highly sensitive to mass balance changes, and estimate that the ice cap will melt completely by the year 2100.