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Basal hydrology and the dynamic climate sensitivity of Vatnajökull ice cap, Iceland

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The possible role of basal hydrology in amplifying the climate sensitivity of glaciers and ice sheets has recently been explored from both theoretical and empirical points of view. However, the strength of this hydrological influence is unclear, as are the conditions under which it is significant relative to direct mass balance forcing from climate. In this study, we examine the sensitivity of a temperate ice cap to future climate change using spatially distributed coupled models of ice dynamics and hydrology. We simulate the evolving ice cap geometry, mass balance, velocity structure and subglacial water pressures and fluxes in response to perturbations to a 1961–1990 reference climatology. Basal motion is parameterized as a function of basal water pressure and driving stress. The result of including a dynamic hydrology is, most notably, a spatially heterogeneous distribution of basal motion that need not closely correspond to the driving stress. For Vatnajökull, this contributes to a sectorally organized climate sensitivity whereby low-lying outlet glaciers on the southeastern and southern flanks of the ice cap are markedly more sensitive to warming than glaciers to the west and north. For a prescribed warming rate of 2 °C per century, these southern outlets retreat 20–30 km in 200 years as compared to $\sim$10 km for the northern outlets. While this sensitivity is partly attributable to the maritime environment and particular glacier hypsometries, simulated mean annual basal velocities for the southern outlets exceed 100 m a^{-1} as compared to 20–50 m a^{-1} for other outlets and are strongly influenced by the distribution of subglacial water. Numerical experiments show that amongst various complexities added to the model (e.g., longitudinal stress parameterizations, geothermal heat sources) the dynamic hydrology makes the greatest contribution to increasing the ice cap sensitivity to climate. Despite the evidently discriminating role of hydrology, we find that increased water production (melt and rain) in response to climate

warming has a very modest effect on future glacier dynamics in the simulations. Any flow enhancement promoted by increased water delivery to the bed is largely offset by the overall reduction in driving stress due to glacier thinning. This suggests that the influence of hydrology on Vatnajökull dynamics is nearly fully realized at present.