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Modelling the Holocene and future evolution of Monacobreen, northern Spitsbergen

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Monacobreen is a 40 km long surge-type tidewater glacier in northen Spitsbergen. The glacier flows down from Isachsenfonna (∼1000 m a.s.l.), and drains an area of about 400 km̂2. The longitudinal surface profile is smooth and the mean slope is small (0.027). During 1991-1997 Monacobreen surged and advanced by about 2 km, but the front did not reach the maximum LIA stand. Since 1997 the glacier front has receded over a distance of 2.5 km.
In this study Monacobreen is modelled with a Minimal Glacier Model, including a parameterization of the calving process as well as the effect of surges. The glacier is modelled as a 5 km wide flowband, to which 10 tributary glaciers and basins supply mass when they have a positive budget. The bed profile is not known, but supposed to be similar to that of Kronebreen, which flows from the same plateau into the opposite direction.
The model is driven by a well-constrained ELA history derived from lake sediments of a nearby glacier catchment (Røthe et al., 2015), in combination with meteorological data from 1899 onwards. The model is calibrated by optimising a surge parameter and the reference value of the ELA. The simulated glacier length is in good agreement with the observations: the maximum LIA stand, the front position at the end of the surge, and the 2.5 km retreat after the surge (1997-2016) are accurately reproduced.
The effect of surging, with a surge cycle of 100 years, appears to be limited. Directly after a surge the initiated mass-balance pertubation due to a lower mean surface elevation is about -0.2 m w.e./yr. This only has a modest effect on the long-term evolution of the glacier.
The simulation suggests that the major growth of Monacobreen after the Holocene Climatic Optimum started around 1500 BC. Monacobreen became a tidewater glacier around 500 BC, and reached a size comparable to the present state around 500 AD. After that the length of the glacier has fluctuated within a range of about 5 km. The e-folding time scale appears to be of the order of 350 years.
For the mid-B2 scenario (IPCC, 2007), which corresponds to a ∼2 m/yr rise of the ELA, the model predicts a volume loss of 20 to 30 % by the year 2100 (relative to the 2017 volume). For a 4 m/yr rise in the ELA this is 30 to 40 %. However, much of the response to 21st century warming will come after 2100.

References:

IPCC, Climate Change (2007), The Physical Science Basis. Cambridge University Press.

Røthe T.O. et al. (2015): Arctic Holocene glacier fluctuations reconstructed from lake sediments at Mitrahalvøya, Spitsbergen. Quat. Sci. Rev. 109, 111-125.