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Distributed modelling of the regional climatic equilibrium line altitude of glaciers in the European Alps

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Abstract

Glaciers are among the key indicators of ongoing climate change. The equilibrium line altitude is a theoretical line which defines the altitude at which annual accumulation equals the ablation. It represents the lowest boundary of the climatic glacierisation and, therefore, is an excellent proxy for climate variability. In this study we introduce a simple approach for modelling the glacier distribution at high spatial resolution over entire mountain ridges using a minimum of input data. An empirical relationship between precipitation and temperature at the steady-state equilibrium line altitude (ELA_0), is derived from direct glaciological mass balance measurements. Using geographical information systems (GIS) and a digital elevation model, this relationship is then applied over a spatial domain, to a so-called distributed modelling of the regional climatic ELA_0 ($rcELA_0$) and the climatic accumulation area (cAA) of 1971–1990 over the entire European Alps. A sensitivity study shows that a change in $rcELA_0$ of ±100 m is caused by a temperature change of ±1 °C or a precipitation decrease of 20% and increase of 27%, respectively. The modelled cAA of 1971–1990 agrees well with glacier outlines from the 1973 Swiss Glacier Inventory. Assuming a warming of 0.6 °C between 1850 and 1971–1990 leads to a mean $rcELA_0$ rise of 75 m and a corresponding cAA reduction of 26%. A further rise in temperature of 3 °C accompanied by an increase in precipitation of 10% leads to a further mean rise of the $rcELA_0$ of about 340 m and reduces the cAA of 1971–1990 by 74%.

Keywords: Glacier, Climate at Equilibrium Line Altitude, Climate Change, Geographical Information Systems