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# A simple model to better understand the Alpine glacier advance and retreat around the end of the Little Ice Age

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Glaciers in the Alps reached their last maximum extent at the end of the Little Ice Age (around 1850). The cause of the preceding advance and the following retreat is still debatable. Different studies attributed this evolution to temperature, winter precipitation, volcanic radiative cooling, or black carbon deposition on snow.

We developed a simple model for yearly glacier volume changes. The model includes air temperature, precipitation, tropospheric and stratospheric aerosols, and black carbon concentration in snow. The effect of these forcings is implemented using mass balance sensitivities, which are partly derived from literature. For temperature and precipitation, different reconstructions were considered. The tropospheric and stratospheric aerosols are model-based. For black carbon, we used ice core measurements from Colle Gnifetti, which is located at the border between Switzerland and Italy. We conducted a great number of simulations between 1700 and 2000, in which we explored the uncertainty range of the sensitivities as well as of the forcings. The model was applied to a number of glaciers in the Swiss Alps, and simulated volume changes were compared with available geodetic mass balances. With our approach, we are able to attribute the simulated changes in glacier volume to the aforementioned forcings. Our results indicate that tropospheric and stratospheric aerosols could be crucial for explaining the rapid glacier advance in the first half of the 19th century and the subsequent retreat. However, the substantial glacier mass loss over the last 150 years is primarily driven by changes in air temperature.