Summary

In densely populated high mountain regions such as the European Alps, glaciers are an inherent component of the Alpine culture, landscape and environment. They represent a unique resource of fresh water for agriculture and industry, an important economic component of tourism and hydro-power production, and a potential source of serious natural hazards. Due to their proximity to the melting point, glaciers are considered among the best natural indicators of global climate change. Mountain glaciers have become the leading icon in the current debate on climate change and on the uniqueness of present-day changes as compared to the variations which occurred during the Holocene period. Although numerous studies have investigated the relationship between glaciers and climate change, glacier-climate studies that focus on an entire mountain range and integrate in-situ measurements, remote sensing data and modelling approaches, as proposed by modern monitoring strategies, have for the most part been lacking.

It is to fill this gap in our understanding that this study undertakes to investigate glacier fluctuations in the European Alps after 1850. Glacier inventories, in-situ measurements and a numerical model (based on an empirical relationship between precipitation and temperature at the glacier steady-state equilibrium line altitude) are used in combination with a digital elevation model and GIS techniques to analyse the glacier fluctuations between 1850 and the end of the 21st century of the entire Alpine mountain range.

Overall area loss after 1850 is calculated using different methods as being about 35% until the 1970s, when the approximately 5,150 Alpine glaciers covered a total area of 2,909 km^2. This loss reached almost 50% by 2000. Rapidly shrinking glacier areas, spectacular tongue retreats and increasing mass losses are clear signs of the atmospheric warming observed in the Alps during the last 150 years and its acceleration over the past two decades, culminating in an ice loss of another 5–10% of the remaining ice volume during the extraordinary warm year of 2003. From the model experiment it is found that for Alpine glaciers, a change of ±1 °C in 6-month summer temperatures would be compensated by an annual precipitation increase/decrease of about 25%. A summer temperature rise of 3 °C would reduce the glacier cover of the reference period (1971–1990) by some 80%, or up to 10% of the glacier extent of 1850. In the event of a 5 °C summer temperature increase, the Alps would become almost completely ice-free. Annual precipitation changes of ±20% would modify such estimated percentages of remaining ice by a factor of less than two.

The presented study demonstrates how modern monitoring strategies can be applied for the investigation of glaciers of an entire mountain range, and that the probability of glaciers in the European Alps disappearing within the coming decades is far from slight.

The thesis consists of a collection of five papers; the studies reported on were carried out within the framework of the EU-funded ALP-IMP project and of the World Glacier Monitoring Service.

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