Shrinking glaciers in the European Alps: the Case of the Gepatschferner

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The decrease in extent and volume of mountain glaciers represents one of the most visible consequences of climate change in mountains. Mountain glaciers are commonly regarded as a sensitive instrument to observe the combined effects of the changes of a number of climatic variables such as temperature, solar radiation, evaporation and precipitation. With the exception of some maritime regions, glaciers are retreating worldwide. Glaciers in the European Alps are no exception with smaller glaciers disappearing at an alarming rate and larger glaciers shrinking visibly in extent.

Glacier variability alone, however, does not present a clear sign of human-induced global warming. Since the end of the last ice age in Europe (ca. 8000 B.C) the Alps have seen several alternating phases of glaciations and near ice-free conditions. The last large deglaciation occurred during the Middle Ages, which can be easily traced by the records of high-altitude mines that have since long disappeared under advancing glaciers. The last period of glacier advance, in the so-called ‘Little Ice Age’, reached its maximum during the middle of the 18th century. From 1850 to 1980, glaciers in the European Alps lost approximately one third of their area and one half of their mass. Since 1980, another 20 - 30 percent of the remaining ice has been lost. With about 50 percent of the observed temperature increase in the 20th century estimated to come from variations in solar energy output a large part of the observed glacier retreat appears to be ‘natural’ deglaciation at the beginning of a warm period after a minor cold fluctuation.

Even if human-induced ‘global warming’ may not be the only source contributing to glacier variations the effects of shrinking glaciers have to be considered as a serious problem for many countries. Glaciers provide crucial water storage, particularly in arid and semi-arid climates where winter precipitation is released in summer coinciding with the season of maximum water demand, both by households and irrigated agriculture. However, even in Europe under temperate climates glaciers provide an important, if not even critical source of water. In addition to a vital source of drinking water, glacier and snow pack melt water feed rivers that provide energy, both by powering hydro electric power stations or as coolant for thermal and nuclear power plants. Pumped storage power plants built in mountains use hydro energy even more directly, benefiting both from the relief energy and the direct supply of glacier melt water into high altitude reservoirs. Austria supplies a considerable amount of peak-load energy into the European power distribution grid that is mostly generated from such glacier-fed hydroelectric power stations. With shrinking glaciers, the question if water supplies for these power stations are in peril is of obvious importance. In an intense discussion on the proposed expansion of alpine power stations estimates of future glacier-fed run-off are a fundamental piece of information.

With an area of about 22 km² the Gepatschferner, situated in Northern Tyrol (Austria), is one of the largest glaciers of the eastern Alps. It extends over an altitude range of nearly 1500 m draining into a reservoir above the Feichten power station, which generates an average 600 GWh per year. The historical glacier variation is dramatically visible by comparing two images of the glacier that span nearly a century from 1904 (Fig. 1) to 2000 (Fig. 2). Even more evident than the reduction in length is the reduced volume of the glacier. Variations in glacier volume are, however, not measured by the standard surveying method that simply observes length variations and the displacement of markers placed on the glacier surface. To estimate mass loss or gain surveys in glacier surface elevation over the entire glacier are needed. Precise surface elevations are obtained by photogram metric surveys that derive surface elevations from aerial stereo photos. Satellite data are only a useful tool to provide medium-resolution surveys over large areas but lack the resolution required to estimate glacier surface elevation with the necessary precision. Generating Digital Elevation Models (DEMs) from the stereo models and comparing DEMs from different observation periods can calculate mass changes directly.

A comparison of DEMs from 1971 and 1990 reveals that changes in surface elevations varies considerably over the glacier and that both localized increases and decreases have occurred. Perhaps the most intriguing feature is a bulge of more than 20 m high that developed at the terminus of the glacier indicating that glacier ice accumulated during a short period of positive mass balance in the 1970’s at higher altitudes has been carried down. Over the entire glacier a mass loss of 26×10^6 m³ (corresponding to about 0.9 percent of the entire glacier volume) has occurred during the two decades between 1971 and 1990.

While a glacier mass loss of less than 0.5 percent per decade seems not to be remarkable the observation period of 1971 to 1990 is not a typical example of the climatic conditions encountered over the last decades. Glacier mass loss (negative mass balance) is the consequence of a combination of warm summers and a lack of precipitation, both in winter as (at higher altitudes) in summer where fresh snow acts as an effective insulator of glaciers. During the observation period of 20 years, nine years indicated a positive mass balance indicating climatic conditions untypical for the constant increase in summer temperatures encountered in the last century. Based on the visual impression of Gepatschferner in 1904 ablation rates and run-off must have been considerably higher during much of the last century than during the observation period in order to melt such a large glacier. Historic high summer temperatures during the last decade have led to considerable higher mass losses: of the remaining ice volume an estimated total glacier-volume of 5 – 10 percent was lost in the Alps in 2003 alone. Similar high ablation rates in the years to come might pose a problem for the continuing service of power stations.

To put recent results in perspective historical glacier variation data and climatological records need to be collected and analyzed in order to understand the interaction between climate and glacier ablation at Gepatschferner. Since Gepatschferner is among the first glaciers in the Alps that has been mapped with modern methods a number of topographical maps have been published since 1888, which will allow establishing a series of DEMs in order to evaluate the temporal evolution of the glacier mass loss. Correlation of climate and glacier variation may allow predicting run-off under future climate change scenarios and even provide arguments in the discussion of the future development of the hydroelectric power plant in Feichten.

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