Geophysical Research Abstracts,
Vol. 11, EGU2009-14023, 2009
EGU General Assembly 2009

Observed changes in hydroclimatology in the Swiss Alps and their potential geomorphological consequences

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Changes in climate may have profound impacts on landscape forming processes, sediment production and transport, through the way in which they affect air temperature, precipitation, soil moisture, vegetation cover, etc. In this paper we present evidence of changes in hydroclimatology which have been observed in the instrumental record of the past 30-70 years in the Swiss Alps and we present some thoughts on the potential geomorphological consequences of these observed changes on landscape forming processes and landsliding in particular.

In a previous study, the first author investigated trends in mean daily streamflow, air temperature and precipitation records from undisturbed watersheds in Switzerland. The identified trends in streamflow were related to changes in precipitation and air temperature, and correlated with watershed attributes. Based on seasonal analyses of shifts in the daily streamflow distributions, it was found that the natural streamflow regime in Switzerland has changed significantly since the 1960s. The main changes were an increase in annual runoff due to increases in the winter and spring season runoff, an increase in winter maximum streamflow (at about 60-70% of the stations) and in spring moderate and low flow. Changes in precipitation and air temperature, most notably a general warming with a substantial increase in the number of days with minimum daily temperatures above 0°C, explain some of the observed increases in streamflow in the winter and spring seasons. Correlation analyses revealed a strong relationship between streamflow trends and mean basin elevation, glacier and rock coverage (positive), and basin mean soil depth (negative). These relationships suggest that the most vulnerable environments from the point of view of runoff generation are high mountain basins with seasonal snow and ice cover.

The potential geomorphological consequences of the above changes are many. The observed increases in spring moderate and low flows due to more snowmelt and liquid precipitation will likely lead to higher soil moisture content for extended periods of time and an increase in landslide activity due to soil saturation, both in terms of the occurrence of shallow translational slides as well as the motion of large slow-moving earth flows. Most vulnerable are areas below 1300 m where a significant drop in the duration of the snow cover is predicted. In terms of extreme events, it is difficult to identify consistent changes in heavy precipitation which usually trigger shallow landslides in the instrumental record. It appears that the occurrence of these events is rather random. However observations also show that extreme precipitation has a distinct seasonal pattern, and it is the change in seasonality due to climate change that may have a significant impact on storm rainfall and resulting patterns of surface erosion. How landscapes will respond in the next century to climate change is an open question and we need well-designed monitoring with concurrent measurements of hydroclimatology, soil water dynamics, and geomorphic process rates to understand the relevant connections and feedbacks.