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Multi-disciplinary geophysical investigations on a temperate alpine glacier

Lasse Rabenstein (1), Hansruedi Maurer (1), Kaspar Merz (1), and Martin Luethi (2)

(1) ETH Zurich, Geophysics, Earth Sciences, Zurich, Switzerland (rabenstein@aug.ig.erdw.ethz.ch), (2) ETH Zurich, Lab. Hydraulics,Hydrology, Glaciology (VAW), Zurich, Switzerland

A recent increase in organic pollutants found in glacial lake sediments in the Alps may be explained by the release of these pollutants from glacial melt water, 40 years after their intensive use in industry in the 1970's. For a better understanding of this process, it is necessary (i) to quantify the flow dynamics of glaciers (ii) to image preferential flow paths and (iii) to estimate the overall amount of liquid water in the ice body. For that purpose, ground penetrating radar (GPR) and seismic data were acquired on the temperate Rhone Glacier in the Swiss Alps in September 2012.

GPR surveys were performed with pairs of 50 and 25 MHz antennas. The depth penetration of the 50 MHz antenna was limited. More detailed structural information of the glacier bed and underlying sediments could be extracted from the 25 MHz data. They indicate a maximum depth of 130 m of the glacier bed. The GPR amplitudes of the glacial bed reflection vary across the glacier, most probably due to the presence or absence of basal melt water.

A coincident high-resolution seismic profile was acquired using a receiver spacing of 2 m, and shot spacings of 4m and 8 m. Seismic energy was generated with small charges of 100 g dynamite. The source spectrum was relatively broad, ranging from 50 to 1000 Hz. This resulted in a high vertical resolution. The 130 m depth estimate from the GPR survey could be confirmed by the seismic reflection data, which additionally provided a much higher resolution of the glacier bed topography with a continuously visible reflection. We interpreted a series of syncline-anticline structures along the glacial bed reflector as melt water channels. The sequence of syncline-anticline structures correlates well with the appearance and disappearance of strong GPR glacier bed reflections. First break travel time inversions of the surface seismic data yielded velocities of 3320 m/s near the surface, and remarkably constant values of 3720 m/s at depths > 4.5m.

To complement the findings from the surface data, crosshole GPR and seismic data were acquired. Initial analyses of the seismic data confirmed the homogeneous velocity structure obtained from the surface data. However, a clear indication of seismic anisotropy could be observed. The horizontal velocities are approximately 3% faster than the vertical velocities.

Using empirical formulas from effective medium theory, it is possible to estimate the water content within the ice body. The relatively high seismic velocities derived from the surface and the crosshole seismic data indicate that the overall water content within the ice must be lower than 1.5 %.