

## Hot water drilling and glaciological observations at the terminal part of Rhonegletscher, Switzerland in 2007

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### Abstract

After the retreat of Rhonegletscher over a bedrock ridge, a proglacial lake has been forming at the glacier forefront since 2005. The lake and the glacier draw glaciological attention because the retreat may be accelerated by calving into the lake. As an initial investigation into studying the impact of the lake formation on the glacier, hot water drilling and preliminary observations were carried out at the terminal part of Rhonegletscher in the summer of 2007. Eight boreholes were drilled down to the bed and accurate ice thickness was determined from the borehole depth. The ice was 135 m thick at a point 700 m from the terminus and it gradually decreased downglacier. This observation revealed that the ice in this region was significantly thinner than previous estimation by an ice-radar survey. The water level in the 135-m borehole showed diurnal variations. The daily minima were steady during the study period at about 10 m higher than the surface elevation of the proglacial lake. After injecting a water jet into the bottom of the borehole, fine sediment was observed in the upwelling water. At some of the other drilling sites, however, scratches on the drilling nozzle suggested that the ice was underlain by solid rock. Thus, it is likely that the glacier bed conditions are inhomogeneous. The rate of change in ice thickness from 2000 to 2007 was determined to be  $-2.8 \text{ m a}^{-1}$ , which indicates that glacier thinning has accelerated in the 21st century.

### 1. Introduction

Rhonegletscher in the Swiss Alps is one of the most well-documented glaciers in the world. The changes in the terminus position have been recorded in photographs and maps since the 18th century, from which a drastic retreat can be seen over the last 150 years. The changes in glacier length and ice volume from 1874 to 2000 are reported as  $-1800 \text{ m}$  and  $-0.6 \text{ km}^3$ , respectively (Cryospheric Commission of the Swiss Academy of Sciences, 1881–2008; Zhano, 2004; Bauder *et al.*, 2007). Despite the recent warming trend, the retreat rate has decreased in the late 20th century because the glacier retreated over a changing bed slope. The terminus retreated over a steep slope in the 20th century, and then became nearly stagnant on a transverse rock ridge.

Although the changes in glacier length have been well recorded, only a few comprehensive glaciological observations have been carried out in Rhonegletscher.

In the late 19th century, Mercanton (1916) conducted various field observations, including mass balance and ice flow speed measurements. Mass balance distribution over the glacier was studied in detail during the period of 1979–1987 (Funk, 1985; Chen and Funk, 1990) and the mass balance was parameterized to the regional climate. A brief summary of the field observations of the past was given by Carlen (2005). These observational data have been used for numerical modelling to reconstruct mass balance history (Huss *et al.*, 2008) and observed changes in the length and surface elevation of the glacier (Stroeve *et al.*, 1989; Wallinga and van de Wal, 1998; Sugiyama *et al.*, 2007).

The ice thickness was measured in detail with an ice radar along 12 profiles across the glacier and a bed rock elevation map was constructed by interpolating the profiles (Zahno, 2004). One of the interesting features in the bedrock topography is an over deepening beneath the terminal part of the glacier. There is a bedrock ridge in front of the current terminus, and behind this point the bed elevation decreases upglac-