Thermal structure and long-term mass balance of polythermal Gornergletscher

Martin Lüthi[1], Michael Thalmann[1], Nico Mölg[1], Alessandro Cicoira[1], Sebastiano Rusca[2]

[1]Department of Geography, University of Zurich, Zurich, Switzerland
[2]ETH Zurich, Autonomous Systems Laboratory (ASL), Zurich, Switzerland

martin.luethi@geo.uzh.ch

Keywords: glacier; mass balance; albedo; polythermal ice; drone

1. Project description

Gornergletscher is the only large polythermal glacier of the Alps. Even in the terminus area at 2500 m a.s.l. the glacier ice is at subfreezing temperatures, with the central portion of the glacier at -2°C (Ryser et al, 2013). The cold ice is well visible at the surface with its bright, white color, in stark contrast to the adjacent temperate glacier parts which are covered with dust and appear grey (Figs. 1 and 3). The impermeable cold ice leads to the formation of deeply incised streams and lakes on the glacier surface which are unique in the Alps (Fig. 1; Renaud, 1936).

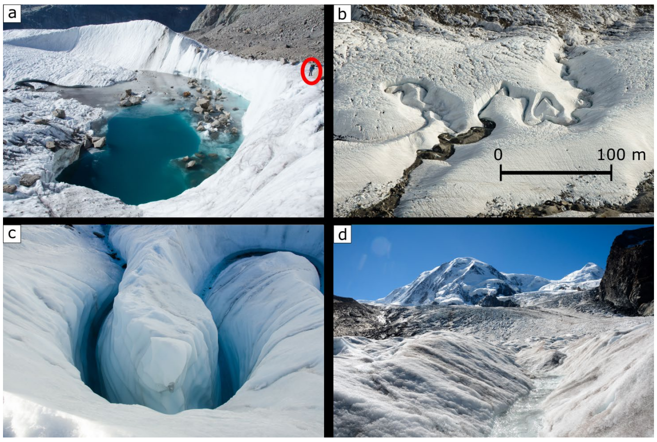

Figure 1. The cold ice in the ablation zone of Grenzgletscher leads to various unique features. Deeply incised, persistent surface streams and lakes are due to the impermeable ice. The bright white surface is due to air bubbles in the ice.

Such surface features are common on arctic glaciers and the marginal areas of the Greenland Ice Sheet. Much speculation prevails on the origin of the dark ice and its impact on melt rates (e.g. Wientjes and Oerlemans, 2010). Gornergletscher is ideally suited to investigate such questions, since surface processes on cold ice can be investigated right adjacent to temperate ice at the same elevation and exposition.

2. First results

During the past several years, we performed a set of low-impact measurements on the glacier terminus. Several near-surface temperature measurements in shallow boreholes showed that the clear, bubble rich surface is indeed at sub-freezing temperature of about -1°C at 1 m beneath the glacier surface.

Measurements of long-term ice melt were performed on cables frozen into the ice over the whole glacier thickness, which were installed a decade ago in boreholes to measure subglacial water pressure, ice deformation and temperature. Readings of lengths between marks on these cables reveal a total ice melt of 50-100 meters during 10 years (Fig. 2; Thalmann, 2019). Surprisingly, evaluation of these data with a degree-day melt model shows no clear correlation between ice melt rates and surface albedo, as measured in-situ and derived from satellite imagery (Thalmann, 2019). Consequently, processes involving the abundant and dark cryoconite holes might be responsible for locally enhanced melt, that cancels the effect of the high albedo within the areas exposing cold ice on the surface.

In addition to these in-situ measurements, we flew different types of drones with thermal and optical cameras in 2018 and 2019. One part of the terminus was mapped in 2019 at dusk and during daylight with a drone carrying multispectral, thermal and optical cameras simultaneously. These thermal images reveal an intricate pattern of high-and low-emission areas on the glacier surface, linked to streams, lakes, water-filled cryoconite holes within the ice and further patterns that are not easily attributable to surface features (Fig. 3). First results of the analysis of these images with neural-network based classification algorithms elucidate several classes of features with different characteristics.

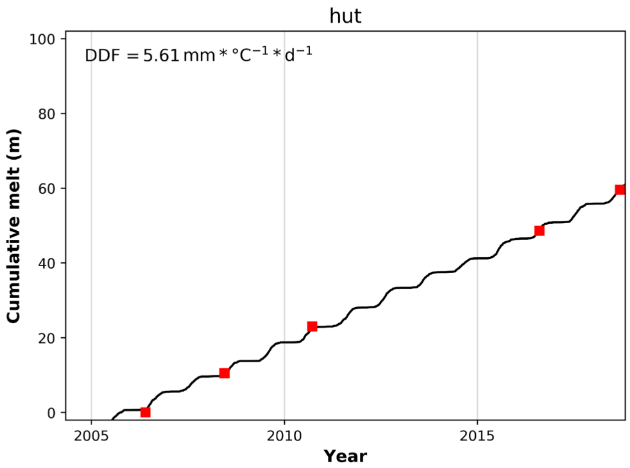

Figure 2. Long-term measurements of ice melt (red dots) on cables frozen into the ice can be interpreted with results from a degree-day melt model (solid line).

Research on all topics mentioned above will continue in the following years. The long-term ablation measurements on the cables frozen into the glacier will be performed every 1-2 years. The identification of optical emission classes detected by analysis of the multispectral images with in-situ observations will be continued. The polythermal structure of the whole glacier terminus with respect to mass balance, surface hydrologic features such as streams and lakes, will be further investigated within the frame of master projects.

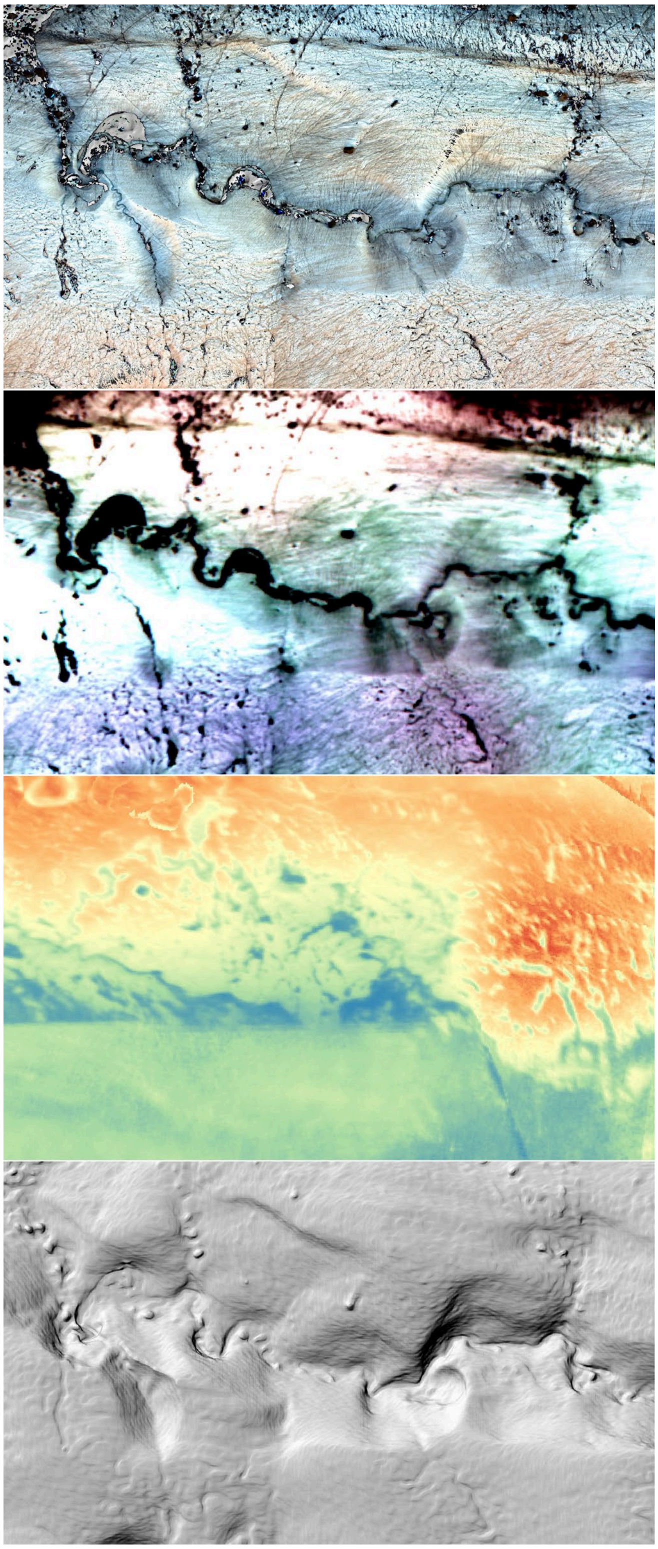

Figure 3. Maps of a part of the glacier surface derived from multispectra and thermal drone imagery elucidate a complex pattern of morphological and thermal structures around a stream channel. (a) color-stretched RGB image, (b) false-color image with three channels of the multispectral camera, (c) thermal emission image (blue: cold; red: warm), (d) hill-shade of a digital elevation model derived from the RGB drone imagery.

References

Renaud, A. (1936). Les entonnoirs du glacier de Gorner. Denkschriften der Schweizerischen Naturforschenden Gesellschaft, 71(1): pp. 27.

Ryser, C., Lüthi, M., Blindow, N., Suckro, S., Funk, M., and Bauder, A. (2013). Cold ice in the ablation zone: its relation to glacier hydrology and ice water content. Journal of Geophysical Research, 118(F02006):693–705.

Thalmann, M. (2019). The effect of cold ice on the ablation of Gornergletscher. Master's thesis, Univ. Zurich, Switzerland.

Wientjes, I. and Oerlemans, J. (2010). An explanation for the dark region in the western melt zone of the Greenland ice sheet. The Cryosphere, 4:261–268.

Scientific publications and public outreach 2019

Theses

Thalmann, M., The effect of cold ice on the ablation of Gornergletscher, Master Thesis, Universität Zürich, 2019.

Address

Department of Geography, 3G
University of Zurich
Winterthurerstrasse 190
CH-8057 Zurich

Contacts

Dr. Martin Lüthi
Phone: +41 44 635 5146
e-mail: martin.luethi@geo.uzh.ch