Permafrost in the Swiss Alps after the hot summer 2022

Jeannette Noetzli *, Cécile Pellet ** and the PERMOS Scientific Committee ***

** WSL Institute for Snow and Avalanche Research SLF / 7260 Davos Dorf / jeannette.noetzli@slf.ch*
*** University of Fribourg / 1700 Fribourg / cecile.pellet@unifr.ch*

Weather conditions 2021/2022

Snow

- Average winter start in November 2021
- Snow heights slightly below average North of the Alps above 2000 m asl. and extremely below average South of the Alps
- Snow vanished about one month earlier than usual

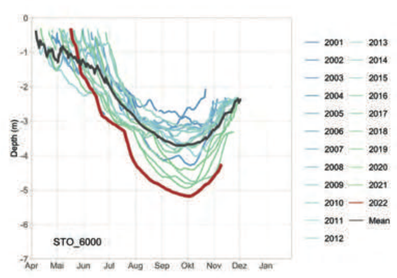
Air temp.

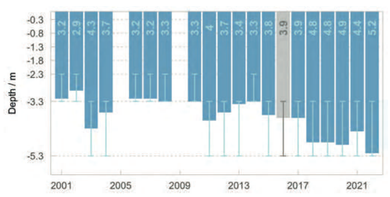
- Mild winter and spring (mainly Feb. and May)
- Second warmest summer with three heat waves
- Warm autumn so far

Source: MeteoSwiss Klimabulletins, SLF Winterbericht 2021/2022

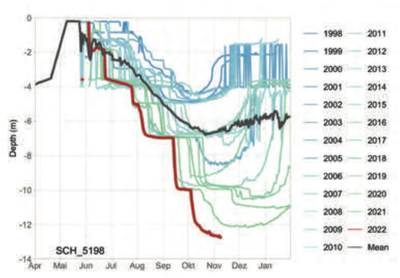
0 °C isotherm and active layer thickness

Stockhorn (VS, 3400 m asl)





Schilthorn (BE, 2900 m asl)



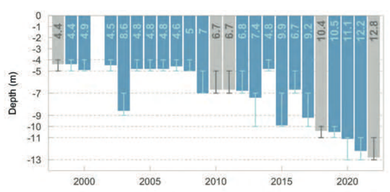


Figure 3a, top: Depth of the 0 °C isotherm in summer 2022 compared to previous years for the boreholes Stockhorn (left) and Schilthorn (right).
Figure 3b, bottom: Active layer thickness (ALT) at selected boreholes. Grey bars indicate guessed values (in 2022 due to the ongoing thawing season). Error bars indicate the depths of the sensors used for linear interpolation of the ALT.

Active layer thickness in 2022

- Early start of the thawing season
- Record ALT for the majority of boreholes expected in 2022
- ALT not yet reached for several boreholes

Permafrost temperatures

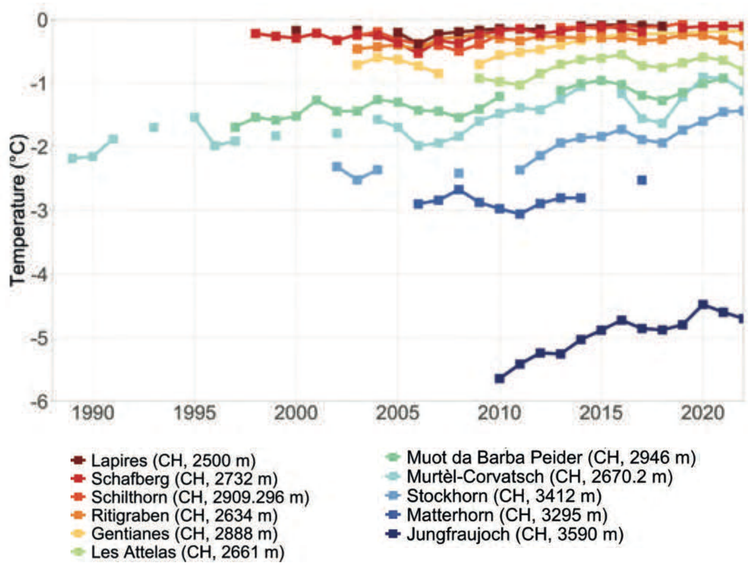


Figure 4: Annual mean temperatures at 10 m depth in selected PERMOS boreholes. Means are calculated for hydrological years.

Rock glacier velocities

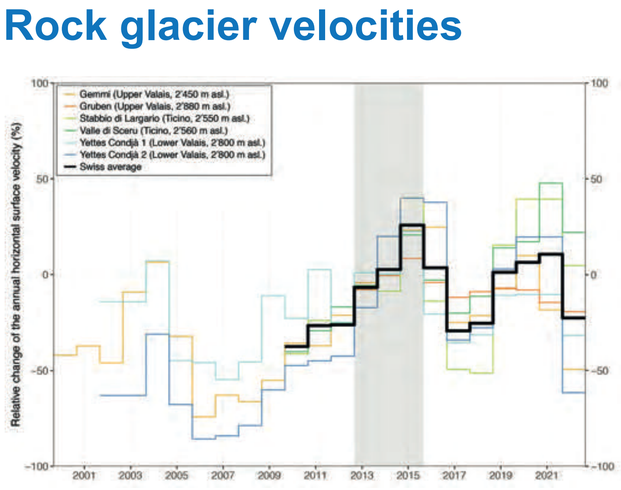


Figure 5: Relative change of horizontal rock glacier velocities from year to year. Data are shown for the sites where 2022 data is already available.

Permafrost creep in 2022

- Rock glacier velocities decreased in the hydrological year 2022 at all sites, where data has already been processed
- This is likely because of the cooler year 2021 and winter 2021-2022 and because the warm thermal conditions from summer 2022 have not yet reached large depth

Ground surface temperatures

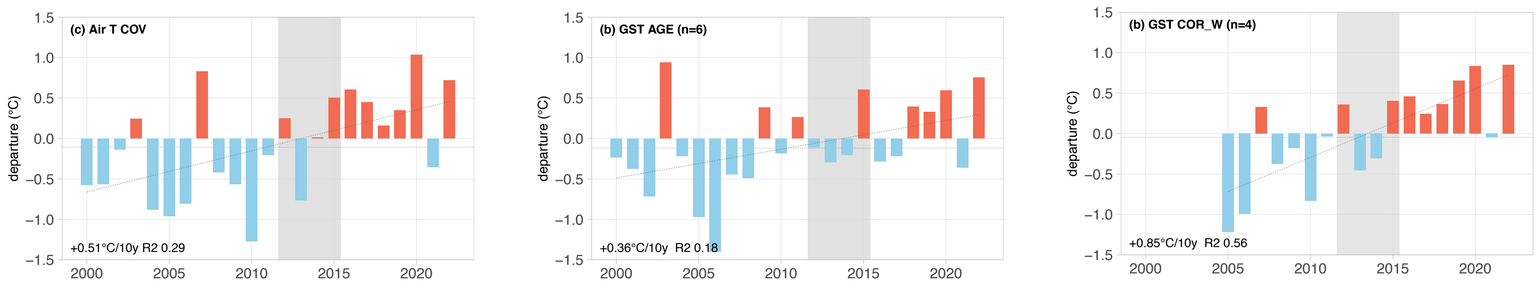


Figure 1: Deviation of the mean annual ground surface temperature (MAGST) from the 2012–2015 mean at two sites: on rock glacier Aget (VS, middle) and in steep bedrock at Corvatsch (GR, right). The air temperature anomaly at Corvatsch is shown on the left (Data: MeteoSwiss). The number in brackets is the number of individual loggers used. The dashed line indicates the trend for the entire time series, the dotted line the deviation 2001–2020.

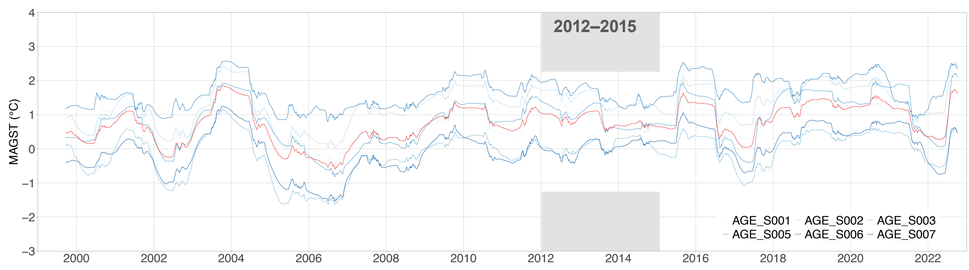


Figure 2: Running annual mean of the ground surface temperature (MAGST) for rock glacier Aget (VS). Individual measurement locations are shown in blue colors, the mean of all 6 measurement locations is shown in red. The reference period used in Figures 1 and 5 is indicated in grey.

Surface conditions in 2022

- MAGST increased strongly after a cooler year 2021 and is on a very high level
- This results from an early snow melt (2-3 weeks earlier than average) and high summer air temperatures

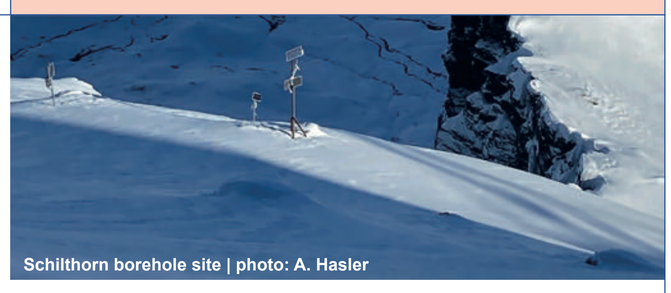
How did the hot summer 2022 affect the permafrost in the Swiss Alps? First results from PERMOS show:

Warm near the surface!

- very warm conditions at the surface
- record active layer thickness at most sites
- continued decrease in permafrost resistivities (increase in unfrozen water content)

Colder below!

- that the summer heat has not yet arrived at depth
- permafrost temperatures at 10 m depth decreased due to a cold 2021
- a decrease in rock glacier velocity



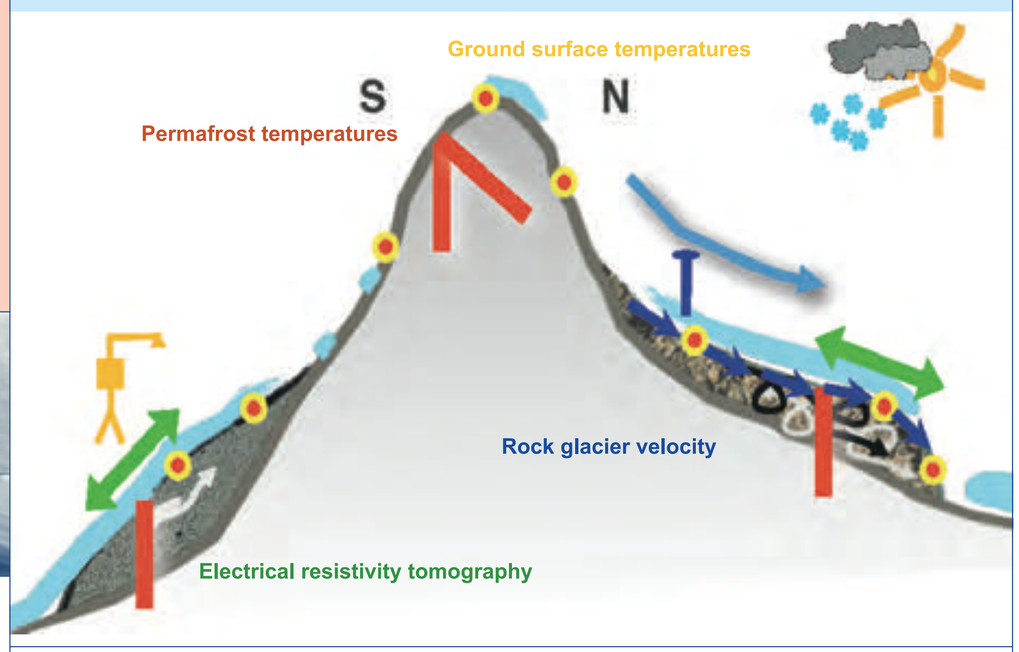
Thermal conditions below the active layer in 2022

- General decrease of the permafrost temperatures at 10 m depth. Temperatures at 10 m depth reflect the temperatures of the previous year 2021, which was colder than 2022 and 2020.
- Record permafrost temperature at 20 m depth. At larger depth (>20 m) ground temperatures reflect long term changes and are not affected by seasonal conditions.

Permafrost Monitoring

Permafrost is classified as an **Essential Climate Variable (ECV)** by the Global Climate Observing System (GCOS) because of its sensitivity to changes in climatic conditions.

The Swiss Permafrost Monitoring Network (PERMOS) documents the state and changes of permafrost in Switzerland based on (1) **ground temperatures** measured in boreholes; (2) changes in **ground ice content** determined by geophysical methods and (3) **rock glacier velocities** measured by terrestrial geodetic surveys.



Permafrost resistivities

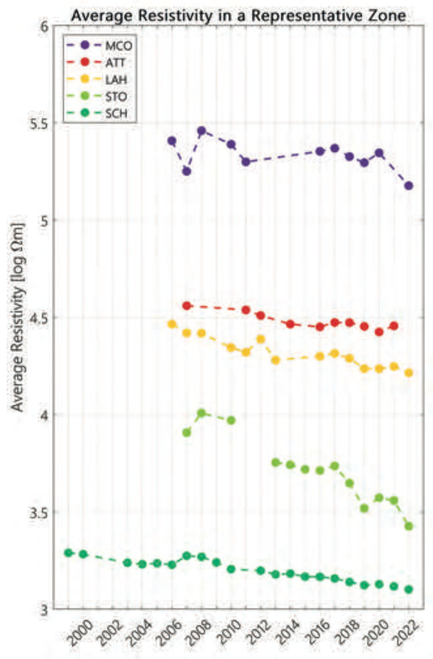
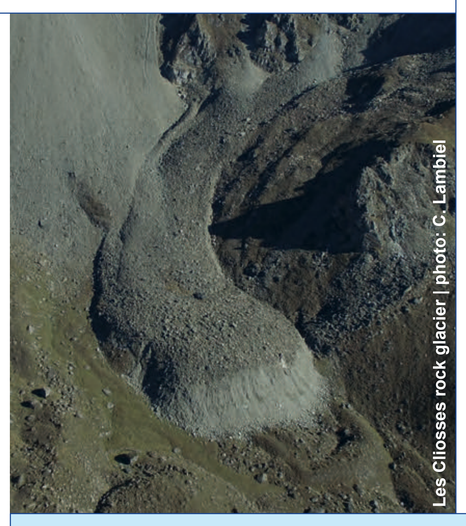


Figure 6: Average electrical resistivities of the permafrost zone at the end of summer for the 5 ERT sites in the PERMOS Network.

Ground ice loss in 2022

- Continued decrease in permafrost resistivity
- This points to a continued increase in unfrozen water content and is interpreted as loss of ground ice



*** PERMOS Scientific Committee

Dominik Amschwand, Jan Beutel, Alessandro Cicoira, Reynald Delaloye, Chantal del Siro, Isabelle Gärtner-Roer, Christian Hauck, Christin Hilbich, Martin Hoelzle, Robert Kenner, Mario Kummert, Christophe Lambiel, Tamara Mathys, Coline Mollaret, Sarah Morard, Raphael Moser, Jeannette Nötzli, Cécile Pellet, Marcia Phillips, Cristian Scapozza, Andreas Vieli, Sebastian Vivero, Daniel Vonder Mühll, Samuel Weber, Julie Wee

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