

Long-term monitoring of permafrost temperatures in the Jungfrau east ridge and Jungfrau summit

Marcia Phillips^{1,2}

¹WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland

²Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland

phillips@slf.ch

Part of this programme: PERMOS, GTN-P, FOEN, Amt für Wald und Naturgefahren Kanton Bern, SLF Permafrost network

Keywords: mountain permafrost; frozen rock walls, thermal regime, long-term permafrost monitoring

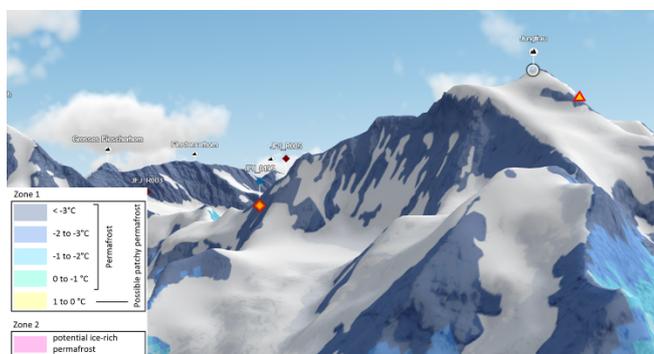


Figure 1: Orange diamond: Position of the borehole in the northern flank of the Jungfrau east ridge. Orange triangle: position of the boreholes near the summit of the Jungfrau (Permafrost and ground ice map of Switzerland (Kenner et al. 2019). Map displayed using maps.wsl.ch).

1 Jungfrau east ridge borehole

The sub-horizontal borehole in the Jungfrau east ridge is located at 3590 m asl (Figure 1, orange diamond) in the northern flank of the ridge. It is 20 m long and is equipped with 9 thermistors and a data logger. Rock temperatures currently vary between around -3.2°C and -6.2°C (Figure 2). Due to the time lag with depth, the highest rock temperatures are registered in winter and the lowest ones in summer.

The Jungfrau borehole temperature data indicate a clear warming at all depths (Figure 2), as do other borehole data measured in steep, ice-poor permafrost rock in the Swiss Alps (Noetzli et al. 2024; PERMOS). In 2024 the highest temperatures in the time series were measured.

In this borehole it is not possible to determine whether active layer thickness (ALT) has changed, as it was drilled from a tunnel inside the mountain outwards – and the end of the borehole is 6 m away from the outer surface of the rock wall. At present, ALT has not yet reached 6 m depth.

The borehole is part of the Swiss permafrost monitoring network PERMOS and the borehole temperature data can be

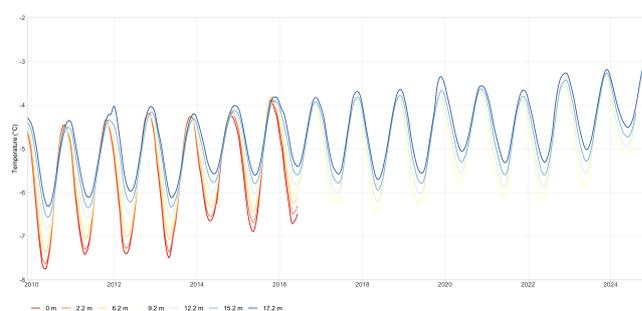


Figure 2: Borehole temperatures (2009–2024) in the Jungfrau east ridge borehole. (Legend: the 0 m thermistor is located 6 m from the outer surface of the rock wall). Data: SLF/PERMOS.

accessed here: <https://www.permos.ch>

2 Jungfrau summit boreholes

In September 2023 two new boreholes were drilled in the western flank of the Jungfrau summit at 4130 m asl (Figure 1, orange triangle; Figure 3, white arrow). They are both 25 m deep and equipped with 20 digital *CS225 Campbell* temperature sensors. One borehole was drilled vertically, the other diagonally. The boreholes are currently the highest and coldest permafrost boreholes in Europe and the data collected there will allow to monitor the evolution of permafrost temperatures and active layer thickness in bedrock at high elevation.

The first months of temperature data (Figure 4) indicate that mean ground temperature in these boreholes is between -7 and -8°C . Maximum ALT in 2024 was 110 cm. Two temperature anomalies can be observed: around April 14, 2024, there was a marked rise in ground temperatures during a warm weather period and in mid-August 2024 a sudden peak in the temperatures at 20–25 m depth was likely induced by water infiltration as high air temperatures were registered in the region, with rainfall at high elevations.



Figure 3: White arrow: Position of the boreholes in the west-ern flank of the Jungfrau summit at 4130 m asl. (Photograph: M. Phillips).

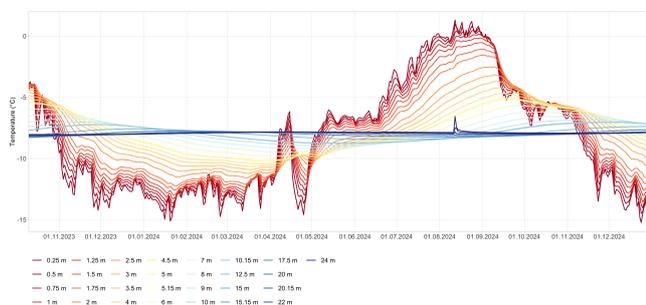


Figure 4: Borehole temperatures in the vertical borehole near the Jungfrau summit. Mean annual ground temperature at 25 m depth is around -7.5°C .

References

- Kenner, R. et al. “Distinguishing ice-rich and ice-poor permafrost to map ground temperatures and ground ice occurrence in the Swiss Alps”. *The Cryosphere* **13**, 7 (July 2019), 1925–1941.
- Noetzli, J. et al. “Enhanced warming of European mountain permafrost in the early 21st century”. *Nature Communications* **15**, 10508 (2024).
- PERMOS (Swiss Permafrost Monitoring Network). <https://www.permos.ch>.

Internet data bases

- GTN-P (Global Terrestrial Network for Permafrost). <https://gtnp.arcticportal.org/data/data-download>.
- PERMOS (Swiss Permafrost Monitoring Network). <https://www.permos.ch>.

Collaborating partners / networks

Amt für Wald und Naturgefahren, Canton Bern. N. Hählen.

Federal Office for the Environment (FOEN). H. Raetzo.

Refereed journal articles

Noetzli, J. et al. “Enhanced warming of European mountain permafrost in the early 21st century”. *Nature Communications* **15**, 10508 (2024).

Address

WSL Institute for Snow and Avalanche Research SLF
Flüelastrasse 11
7260 Davos Dorf
Switzerland

Contact

Dr. Marcia Phillips
Tel: +41 81 417 02 18
E-mail: phillips@slf.ch