First results from PERMOS after the summer 2015 heat wave

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PERMOS

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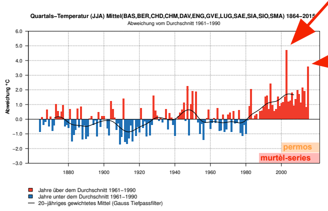
Summer 2015



The hottest summer 2003
- air temp >4.5 °C above the mean 61–90
- earlier start and longer, max in August
- following a very warm winter
- extremely dry

The second hottest summer 2015
- airT >3.5 °C above the mean 61–90
- main heat wave in July, cold June
- new absolute record temperatures
- 0 °C isotherm >4000 m asl. for 6 weeks
- less dry with many thunderstorms

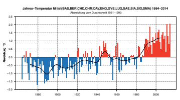


Fig 1: Above: Deviation of summer air temperatures in Switzerland from the long-term mean 1961–1990. Right: Deviation of mean annual air temperatures. Source: MeteoSwiss.

Surface and ground temperatures

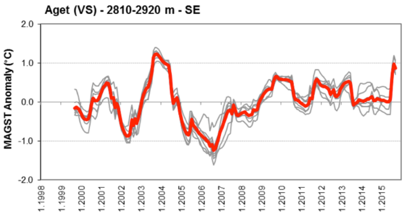
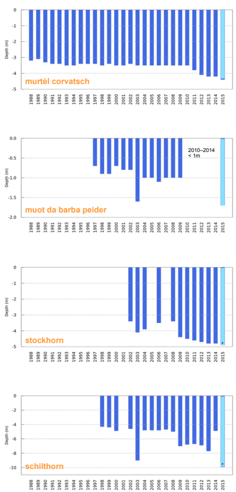


Fig 2. Anomaly of annual running average of ground surface temperatures (MAGST) measured at the PERMOS site Aget, VS. The temporal pattern at other snow rich observation sites is generally similar.



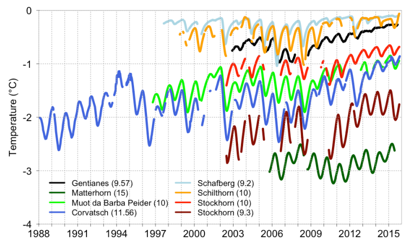


Fig 3. Borehole temperatures at ca. 10 m depth for several sites where the 2015 data has already been obtained. Here, seasonal variations are well visible, but with a time lag of around 6 months. The past 7 years show a warming trend in all of the boreholes. Remarkable are the high winter temperatures in this period.

Fig 4: Maximum active layer thickness (ALT) for selected borehole sites. Note that at some locations (*) the max ALT for 2015 has not yet been reached but is already at a record level (begin of November 2015).

- MAGST strongly increased in the past months and is at a high level, but still lower than 2003
- In winter 14/15 conditions were colder than 02/03 due to a later and longer lasting snow cover
- New record ALT at many sites, high values since 2009
- Warming at depth, e.g. in 10 m, for the 2010er years cleary visible in most boreholes

The record values cannot be explained with the 2015 summer heat wave alone. The previous 6 years have already been exceptionally warm. Due to the inertia of heat diffusion, the response of permafrost below the uppermost meters will mainly be observed at the begin of 2016. The snow conditions of the coming winter will be crucial as they can balance or enhance the effects of summer 2015.

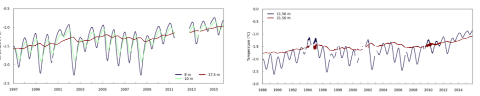
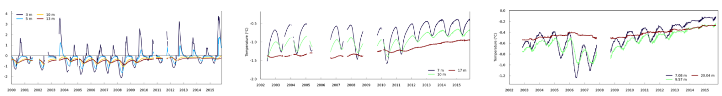


Fig 5: Examples of borehole temperatures measured at PERMOS sites (l to r): Muot da Barba Peider (GR), Corvatsch-Murtèl (GR), Schilthorn (BE), Stockhorn (VS), and Gentianes (VS).



Electrical resistivities

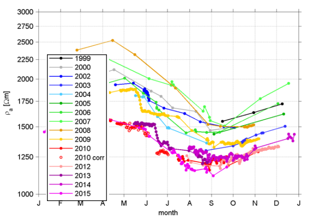


Fig 6. Annual cycles of average apparent resistivities since 1999, taken from the horizontal ERT profile at the location of the borehole on Schilthorn. Figure: C. Hilbich.

Fig 7. Borehole site on Schilthorn BE. The ERT-measurements are taken on a fix horizontal profile between the boreholes and the energy balance station in the back. Photo: J. Nötzli.

- 1 of 5 profiles processed for 2015 so far
- Lowest resistivities ever measured on Schilthorn
- All years since 2009 with lower values than 2003
- Indicates permafrost degradation and unfrozen water

Acknowledgements

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Rock fall activity

- Large number of rock slope failures reported mainly in July and August 2015
- Concentration in permafrost regions above 2500 m asl.
- Most failures occurred near-surface at depths influenced by seasonal temperature variations
- No large, deep-seated events with volumes of 100'000 m3
- Largest event on Grande Dent de Veisivi, VS, 02.09.2015, 80'000 m3, ca. 3400 m asl, W face

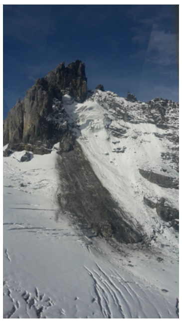
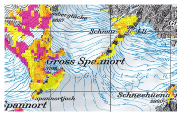


Fig 8. Rock fall from the NE side of Spannort at ca. 3000 m asl in September 2015. Photo: Christian Schindler (Swiss Helicopter).

Fig 9. Map of potential permafrost distribution from BAFU (2006) in the area of Gross Spannort. Yellow colors denote potential patchy permafrost, violet colors indicate that extensive permafrost is likely. Map: ©Swisstopo (JA100118).



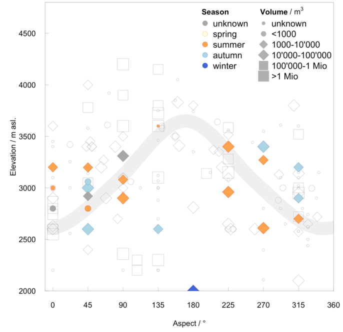


Fig 10. Rock slope failures at high elevations in 2015. For comparison, open symbols show the distribution of all events in the SLF data base. The light grey line sketches the permafrost limit for steep and snow free Alpine rock walls.

more information on: www.slf.ch/ueber/organisation/schnee_permafrost/projekte/felsstuerze_2015/

A combination of high air temperatures warming the rock and ice in cracks and sporadic influxes of water into rock discontinuities has potentially led to failure through temperature-related strength loss and hydrostatic pressure.

Rock glacier velocities

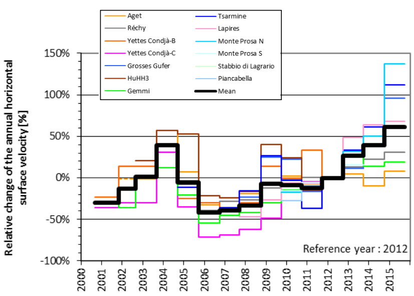


Fig 12. Overview (large picture) and front (inlet) of the Tsamine rock glacier in the Val d'Arolla, VS. Photos: Mario Kummert.

Fig 11. Relative change of annual horizontal velocities of rock glaciers observed within PERMOS. Data from 7 of the totally 14 observed rock glaciers have been processed.

- New record velocities for most sites processed
- Increasing speed since 2006
- Exponential relationship to permafrost temperature
- Displacement rates of several m per year are becoming frequent

Summary and Outlook

- **All observation elements show new record values after summer 2015.**
- **Continously very warm permafrost conditions were measured in the past 7 years.**
- **In this period a signifcant warming in most boreholes at 10 and 20 m depth is visible, noticable are the high winter temperatures.**
- **The recent warming and records are not an effect of the hot summer 2015 alone, but a cumulative result of a series of very warm years.**
- **Surface conditions reach a depth of 10 m after about 6 months time and the full impact of the summer 2015 will only be visible this winter. Snow conditions of winter 2015/2016 will be crucial.**

Re-drilling the Murtèl borehole

To ensure the continuation of the longest time series in mountain permafrost from 1987, a new borehole was drilled in the rock glacier Murtèl-Corvatsch, GR • due to creep the old borehole will likely shear off soon (velocity of ca. 10 cm per year) • drilling campaign in September 2015 in the framework of PERMOS and under the lead of Uni ZH • 60 m depth • a core was taken for the ice-rich part 4–32 m • 3 thermistor chains and an inclinometer will be installed in November 2015.

Fig 13. Illustrations from the drilling campaign, September 2015. Photos: J. Nötzli