A regional signal of significant recent ground surface temperature warming in the periglacial environment of Central Austria

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Long-term data series of ground temperature from the periglacial environment of polar and alpine regions are essential to understand the effects of present global change on the distribution and the thermal characteristics of seasonal and perennial frost-affected areas. Such data series aid to quantify not only the "mean" thermal condition but also outliers and trends at a given monitoring site.

In this contribution up to eleven years of field data from nine different study areas in Austria are presented and discussed. All areas are located in the highest mountain range in Austria, the Tauern Range (max. elevation 3798 m a.s.l.) with its subunits Niedere and Hohe Tauern covering c.9000 km^2 of the national territory (Fig. 1a). The nine study areas are located between latitude 46°55' to 47°22' and longitude 12°44' to 14°41' (Fig. 1a). Altogether 57 ground temperature monitoring sites have been installed in 2006 and 2007 at the nine study areas using one- (at 23 sites) and three-channel (at 34 sites) miniature temperature dataloggers (all manufactured by GeoPrecision, Germany). These monitoring sites range from 1922 to 3002 m a.s.l., consider flat terrain as well as step rock walls, different substrates (coarse debris, fine-grained sediments and bedrock), and include all slope aspect classes adequately. Therefore, this monitoring network with its data series is presently the most comprehensive one in Austria [Kellerer-Pirklbauer, 2014].

Research questions addressed here are related to

a) general ground thermal conditions,

b) potential permafrost occurrence,

c) trends in thermal conditions during the observation period, and

d) regional pattern.

The data analysis focused on quantifying mean thermal conditions as well as statistical significant trends regarding a series of ground temperature derived parameters; i.e. mean annual ground surface temperature (MAGST), maximum surface temperature (MAX), minimum surface temperature (MIN), cumulative sum of freezing degree days (FDD), cumulative sum of thawing degree days (TDD), the surface frost number (F+; cf. Nelson and Outcalt [1987]), days with freeze-thaw cycles (FTC), days with positive temperatures (DPT), ice days (ID) and days with a seasonal snow cover (SCD). Annual, seasonal and monthly values for the above mentioned parameters were quantified. Statistical significant correlations between the temperature derived parameters and number of monitoring years, seasons (DJF, MAM, JJA, SON), and individual months have been tested. Regarding annual mean values, two types of annual data were computed; hydrological years (HY/01.10.-30.09.) and "monitoring years" (MY/01.08.-31.07.). The second annual period was chosen to account for the typical field-work month August, where the temperature data are commonly retrieved from the loggers.

The deviations from the mean annual values (MAGST) of the whole monitoring period at four selected monitoring sites (partly in permafrost, partly in seasonal frost) are exemplarily presented in Fig. 1b-e. These graphs also indicate, respectively, elevation, the MAGST value, and correlation coefficient as well as statistical significance of linear trends. Noteworthy is the following observation depicted in b, c and d. The deviation values and pattern of warmer/colder years compared to the mean are similar with negative deviations during the first 4-5 years of data and positive deviations in the subsequent 3-4 years. All three monitoring sites reveal statistical significant warming during the 8-year observation period 2007/08 to 2014/15. The exception is the monitoring site REI-SUM shown in Fig. 1e, where data series are longer and therefore also include the exceptional warm winter 2006/07. The unusually warm monitoring year 2006/07significantly influenced the linear trend for the entire monitoring period.

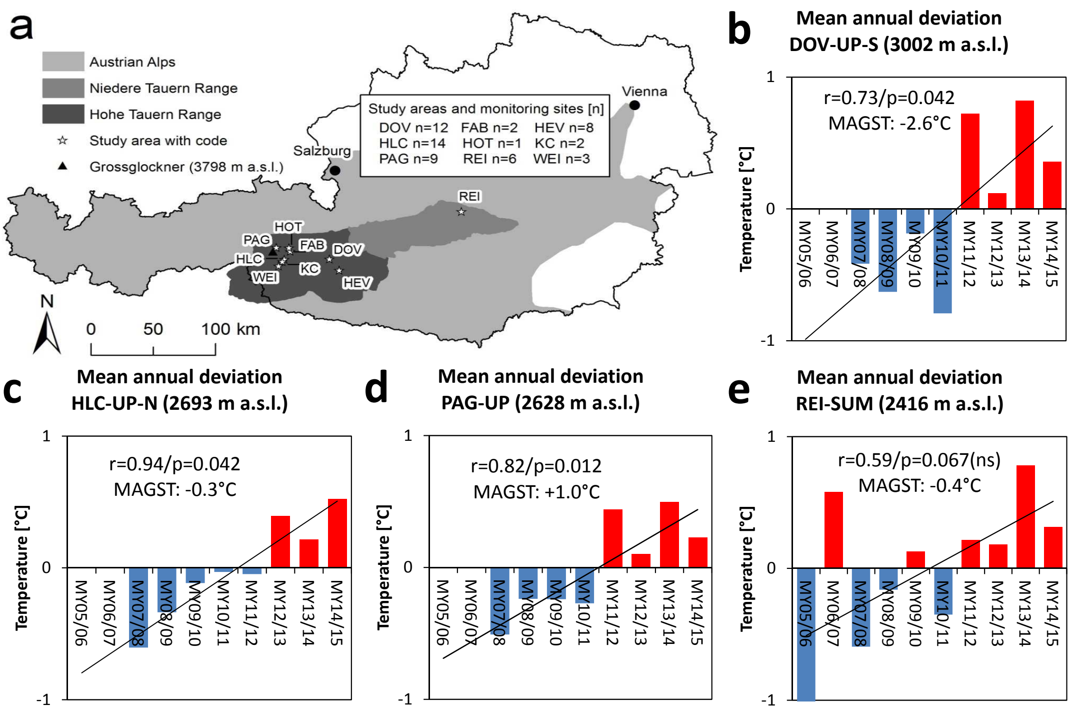

Figure 1: Study areas and selected results: (a) Location of the nine study areas in Austria with number of study sites; (b-e) Temperature deviation from the mean value during the monitoring period based on annual values (MY; 01.08.-31.07) at four sites.

For the site REI-SUM some more in-depth results are presented here. At this site, maximum temperatures (MAX) statistically increased and the surface frost number (F+) statistically decreased during the last years based on annual data. Regarding changes in the different seasons, no significant trends were revealed for spring (MAM) and autumn (SON). However, during summer (JJA) warming is confirmed by significant increases in MAGST, TDD, DPT whereas by a decrease in FDD. On a monthly basis, no statistical significant changes were revealed for JAN, FEB, APR, SEP and OCT. The remaining months show significant changes. Particularly in August several ground temperature derived parameters indicate substantial warming (MEAN, MAX, MIN, TDD, FTC, and DPT).

Based on the available long-term ground temperature data series presented in extracts in this contribution, it was possible to reveal that significant warming of seasonal and perennial frost areas in the central Austria occurred during the last decade. However, exceptional warm weather periods (e.g. warm winter 2006/07) or variations in the seasonal snow cover (onset, duration, thickness, melt-out data) might strongly influence the long-term ground temperature signal. The observations described here highlight the importance of long-term permafrost but also seasonal frost monitoring, an effort which is currently augmented in Austria within the framework of a national permafrost monitoring network (permAT) currently under development [Kellerer-Pirklbauer et al., 2015].

References

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