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Documentation of MeteoSwiss Grid-Data Products

Daily Mean, Minimum and Maximum Temperature: TabsD, TminD, TmaxD

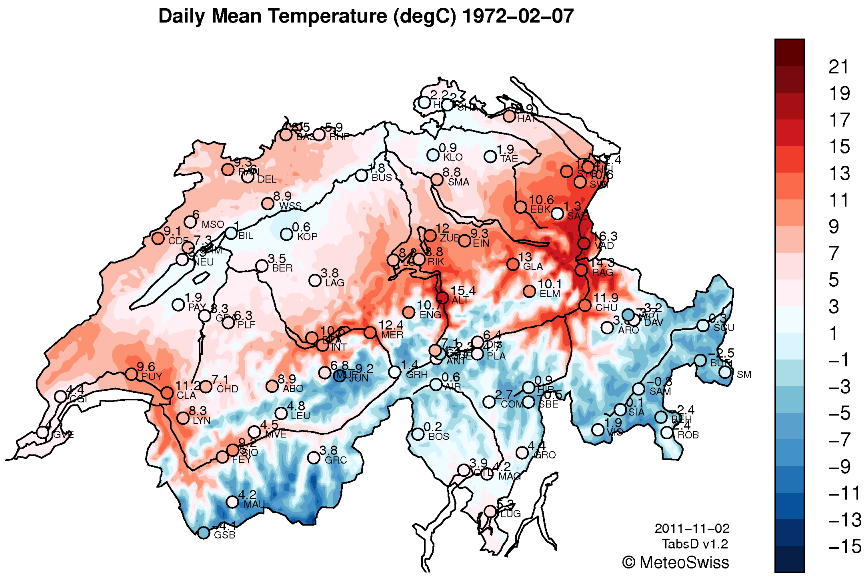

Figure 1: Daily mean temperature (degC) for 7. February 1972. A typical temperature distribution with Föhn.

Variable

Daily mean, minimum and maximum of free-air temperature 2 m above ground level, representative of the average, the minimum and the maximum from midnight to midnight UTC. All products in degrees Celsius.

Application

Agricultural planning and monitoring. Environmental modeling (soil water, ground water, runoff, ecosystems, snow and ice). Weather and climate related economic sectors (tourism, energy, construction engineering). Climate monitoring and climate change downscaling.

Overview

The three temperature datasets describe the km-scale distribution of day-to-day temperature variations in Switzerland during the past decades. (TabsD: 1961-present, TminD and TmaxD: 1971-present). They utilize approx. 90 homogenous long-term station series. The products serve as input for a broad range of modelling applications and planning tasks. Their availability in near real time allows for monitoring weather effects on the environment and on weather-related economic sectors.

Data base

Input for all three data products are near-surface air temperature measurements taken at the operational station network SwissMetNet of MeteoSwiss (MeteoSwiss 2010). To ensure a high degree of long-term consistency in the analyses, the primary data source is a set of high-quality records that have been rectified (homogenized) for the effect of instrument changes and station relocations (Begert et al. 2003, Begert et al. 2005). Since 1982, the number of such records is almost constant and encompasses 84 – 93 measurements for mean temperature every day. (79 – 88 for minimum and maximum temperature.) Before 1980 the number of homogenized mean temperature series has increased continuously from as few as 61 in 1961. For minimum (maximum) temperature, the data records start with 62 (54) stations in 1971. Extreme temperature measurements in the 1960ies were even more scarce, and this is why products TminD and TmaxD are provided from 1971 onwards only.

An additional set of station records with inferior long-term consistency is incorporated in parts of the analyses for TabsD (see Frei (2014)). It encompasses a total of 38 handpicked stations at elevations above 800 mMSL. These auxiliary records are used in the estimation of the vertical temperature variations only (step 1 of the analysis, see below). They are meant to improve the reliability of inversions and other anomalies in the vertical temperature structure during early decades, when only few homogenous records are available at mid and high elevations. Typically, the auxiliary set contributes 10–15 measurements per day.

More detail on the station sample for this product can be found in section 2 of Frei (2014).

Since 1980 measurements at MeteoSwiss station network were continuously automated, so that after about 1990 the vast majority of daily temperatures are determined as the mean (minimum and maximum) of measurements taken in 10-minute intervals from midnight to midnight UTC. Before automation daily mean and extreme temperatures were derived from three manual readings of actual and extreme temperatures. Homogenization has largely rectified inconsistencies from these changes in observation practice (see Begert et al. 2003).

Temperature measurements used in the analysis were all taken 2 meters above ground level, following the guidelines and standards of WMO (WMO 2006) and they are checked rigorously for data quality at MeteoSwiss.

Method

For the construction of TabsD a new deterministic analysis method has been devised, which addresses specifically some of the challenges of temperature interpolation in high mountains. The method is described in detail in Frei (2014) and was also implemented for the territory of Austria (Hiebl and Frei 2015). This section provides a short summary.

The analysis is conducted independently for each day. For daily mean temperature (TabsD) a supra-regional vertical temperature dependence is estimated in a first step. This is accomplished via a non-linear parametric profile, capable of reproducing temperature inversions and warm boundary layers. The fitting procedure is based on non-linear least squares and involves several fitting steps with different subsets of stations. The vertical temperature dependence varies smoothly from the Alpine North to the South side.

In a second step, residuals (i.e. deviations of measurements from the vertical profile) are interpolated by weighting with non-Euclidean distances. To this end, several distance schemes are defined, representing variable vertical layering. Schemes for strong layering insure that information from valley floor stations is transmitted primarily in the along valley direction. The appropriate layering for a particular day is determined through structural analysis from the data itself (see Frei 2014). Non-Euclidean distance weighting turns out to be very essential in reproducing cold-air pools in mountain valleys and the distribution of temperature during Föhn. The concept builds on ideas of Deng and Stull (2005).

The analyses of daily minimum and maximum temperature (TminD, TmaxD) are constructed by spatial interpolation of the difference between temperature extremes and the daily mean, using non-Euclidean distance weighting (step 2 above, Frei 2014). Subsequent combination with the analysis for TabsD ensures that TminD < TabsD < TmaxD for each analysis point.

The digital elevation models used are USGS GTOPO30 (2-km grid, http://eros.usgs.gov) and the SRTM (1-km grid, Farr et al. 2007). DEMs are available with the datasets.

Target users

The daily temperature analyses address needs from many disciplines of natural sciences and offer input for a wide range of modeling applications. These include, among others, the modeling of soil water balance for runoff forecasting, the modeling of economic plants (crops, pasture) for agricultural planning and monitoring, the modeling of snow cover and ice melt for assessing risks of natural hazards (avalanche, slope stability) and for glacier monitoring. In addition, the analyses address needs of several economic sectors, such as tourism and the energy industry, in adapting to and managing the influence from weather and climate. Temperature is also a key variable for the design of heating systems in buildings.

The area-covering analysis of observed temperature also provides a valuable reference for improving the accuracy of model-based temperature forecasts, and for adjusting large-scale climate change scenarios to local conditions. The analysis also serves as a basis for model evaluation and for monitoring interannual climate variations (see e.g. Ceppi et al. 2010). Owing to the daily resolution, such activities may also address the occurrence of extreme weather conditions, such as drought, heat waves, cold spells or rapid temperature changes.

Accuracy and interpretation

Despite its specific design for a mountainous area and the comparatively dense measurement network, the estimation of temperatures for non-instrumented locations has a limited accuracy, which is crucial to consider in applications of the data products.

DTM versus site elevation: The analyses provide temperature estimates for the grid points of a 1-km and a 2-km digital terrain model (DTM), which may differ from the elevation of a location of interest. Users needing estimates for specific locations or on a different DTM will have to correct for elevation differences. A vertical interpolation using 9 surrounding grid points is mostly sufficient for this. The DTM used for the analyses is available with the data products.

Unresolved scales: Several small-scale effects on the temperature distribution are not modeled in the analysis. Among these are all kinds of land cover effects (e.g. lakes and urban heat islands) and the influence of local topography. As a result, it must be expected that spatial variations are underestimated (too smooth), particularly at the scale of the grid-point spacing, and small-scale patterns may display with considerable error in extent and amplitude. This is particularly true for valley cold pools: Their reproduction by the analysis critically depends on the existence of in-situ measurements. Hence cold air pools may be missing completely in un-instrumented valleys (see Frei 2014).

Interpolation uncertainty: The interpolation accuracy has been calculated by leave-one-out crossvalidation over a 10-year period. The mean absolute error for TabsD is largest in winter and ranges from 0.6 (0.9) degC over the Swiss Plateau (Jura) to 1.5 (1.6) degC over the Alps (Southern Switzerland). Particularly large errors are met in inner Alpine valleys (as large as 4 degC), mostly due to systematic overestimates in these cold air pool environments. In all other seasons, interpolation errors are smaller and attain values around 0.6 degC over the Swiss Plateau, 0.7 degC over the Jura, 0.8 degC over the Alps and 0.9 degC in Southern Switzerland. Standard errors for TminD and TmaxD are larger by a few tenths of a degree in winter but comparable to those of TabsD in other seasons. A detailed discussion and additional analyses of cross-validation results are provided in Frei (2014).

Long-term homogeneity: Even though the primary input measurements are of good long-term consistency, the homogeneity of the spatial analysis itself is compromised by changes in the station network. This concerns especially the period 1961-1980 when the network density increased continuously. Crossvalidation errors of the 50-year linear trend (1961-2010) are of comparable magnitude like the station-by-station variations of the trend. This calls for caution using the daily temperature analyses for long-term climate trend studies before 1980. For more detail see Frei (2014, section 4d).

Related products

RprelimD / RhiresD / SrelD: Daily analyses for precipitation and sunshine duration, together with those for daily temperature, provide comprehensive information on weather and climate in Switzerland and are, in combination, useful for many modeling tasks.

TabsM / TabsY / TminM / TminY / TmaxM / TmaxY: Similar to daily mean and extreme temperatures but for the monthly / yearly mean of these parameters. There is no strict consistency between the datasets in the sense that averaging daily analyses does not exactly reproduce monthly and yearly analyses. If monthly/yearly resolution is sufficient, it is recommended to work with the analyses for coarser time resolution.

TanomD9120: The anomaly of daily mean temperature from the long-term mean of the calendar-day (1991–2020). This analysis is particularly illustrative for monitoring purposes, because the long-term topographic temperature signal is removed.

Grid structures

TabsD, TminD and TmaxD are available in the following grid structures:

ch02.lonlat, ch01r.swiss.lv95, ch.cosmo1.rotpol, ch.cosmo2.rotpol, ch.cosmo7.rotpol (analyses on cosmo grids are provided upon special request only)

Versions

Current version: TabsD v1.2, TminD v1.2, TmaxD v1.2

Previous versions: none

Update cycle

Daily temperature grids for day D are calculated in the morning of day D+1. Once every month, the grids are update to include changes of station measurements from ongoing data quality control. The final analysis for a month is available typically on the 15th of the following month. Further updates are produced after major updates in station data homogenization.

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