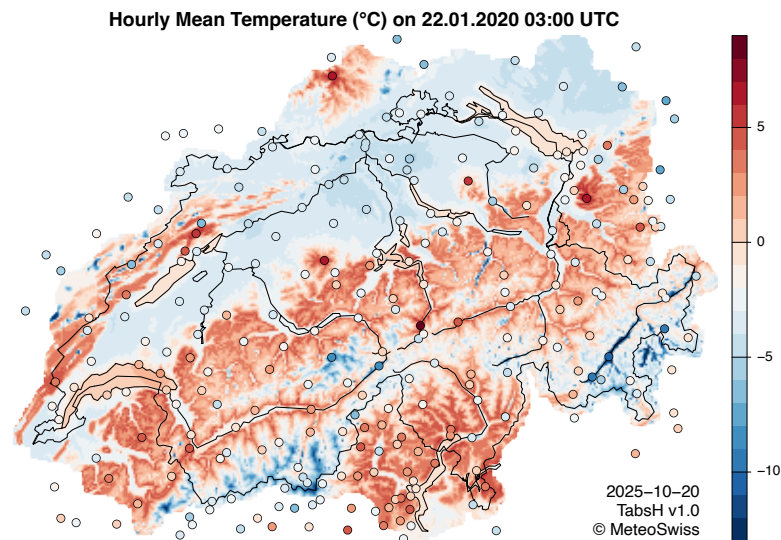




Documentation of MeteoSwiss Grid-Data Products

Hourly Mean Temperature: TabsH



*Figure 1: Hourly mean temperature (°C) for 22. January 2020, 3:00 UTC.
A typical temperature distribution during a basin-scale inversion over the Swiss Plateau.*

- Variable** TabsH represents surface air temperature, 2 m above ground level, representative of the average over civil hours. More specifically, the value at hour HH represents an average of six instantaneous measurements in 10-minute intervals from (HH – 1):10 to HH:00. Values are given in degrees Celsius. An associated data product (TabsHunc) characterizes the standard error of the estimated temperatures in TabsH, also given in degrees Celsius.
- Application** High-resolution physico-chemical modeling of the environment (soil water, ground water, runoff, ecosystems and agricultural crops, snow cover and glaciers). Weather and climate related economic sectors (tourism, energy, construction). Climate change downscaling.
- Overview** The grid dataset describes the spatial distribution and hour-to-hour evolution of surface air temperature on a 1-km grid within and around Switzerland. TabsH is currently available for 7 years (2018-2024), but may be extended to a longer time period, depending on interest and resources. TabsH builds on in-situ measurements at approx. 250 weather stations. It is intended for applications that require explicit resolution of the diurnal cycle.

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Data base

TabsH relies on measurements of near-surface air temperature taken at the operational station network SwissMetNet of MeteoSwiss (MeteoSwiss 2018). It also incorporates data from the near-border sections of the station networks in neighboring countries. (Data obtained from Geosphere Austria, the German Weather Service DWD, MeteoFrance, and the regional agencies (ARPAs) of Valle d'Aosta, Piemonte and Lombardia in Italy). The total number of stations used is 259. The median and minimum number of measurements available at any hour are 258 and 212, respectively. More detail on the station sample for this product, and a map of the station locations, can be found in Frey & Frei (2025, section 2.2).

Measurements in Switzerland are taken automatically at 10-minute intervals. Hourly values are derived by averaging the 10-minutes measurements from (hh-1):10 to hh:00 (civil-hourly mean). Measurements in Austria, Germany, and in the Italian regions Valle d'Aosta and Lombardia are hourly averages as well. In France and the region Piemonte, however, hourly observations were available only as instantaneous values at the full hour. In these cases, pseudo-mean values have been calculated, prior to the analysis, by averaging the two values at the beginning and the end of the hour. The difference in temporal representativity over the hour between the different station networks is accounted for in the statistical method of the interpolation.

Temperature measurements used in the analysis were all taken 2 meters above ground level, following the guidelines and standards of WMO (WMO 2008). The measurements in Switzerland are checked rigorously for data quality by the operational procedures at MeteoSwiss. At the other data providers, verification procedures are in place too, but residual data quality issues have been encountered in the development of TabsH. Therefore, additional tests were conducted on the spatial consistency of the measurements, using a spatial statistical model. Measurements with an absolute deviation of $>10^{\circ}\text{C}$ from the model prediction were excluded.

Method

The construction of TabsH builds on a new statistical method developed specifically to address the challenges of temperature interpolation at sub-daily time scales and in complex topography. The method is described in detail in Frey & Frei (2025). This section provides a short summary.

The method is based on a spatio-temporal dynamic linear model (DLM). It models the spatial and the temporal organization in the data jointly, with the advantage that information in the data is also transferred over time, not just over space like in standard interpolation. This allows to connect patterns in the diurnal thermal cycle to patterns in space, as is desirable when picturing, for example, the dampened / enhanced thermal variations along lake shores / in inner-Alpine valleys. DLM is a conceptual extension of kriging with external drift (KED), a model widely used in spatial climatology, but it involves additional parameters to characterize the temporal dependence of the drift coefficients.

For TabsH, the spatio-temporal DLM is carefully configured to represent the climatic characteristics of the region. A number of spatial covariates is included to describe the (occasionally non-linear) variation of temperature with elevation. Additional spatial covariates are used to model local-scale effects with potentially large amplitudes, such as cold-air pooling (CAP), lake- and valley-effects, and foehn. The predictor set also involves a north-south indicator and west-east gradient to account for large-scale contrasts in the temperature profile and the local effects, such as when an inversion is present to the North, but not to the South of the main Alpine crest, or when foehn is present in the East but not in the West of the domain. Residuals are modelled, spatially, as a zero-mean Gaussian random field with an exponential covariance and a nugget effect. The temporal variation of the covariate coefficients is modelled as a superposition of a slowly evolving trend and several harmonic diurnal oscillations. The amplitude and phase of the latter can vary gradually over time.

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Frey & Frei (2025) illustrate and evaluate the spatio-temporal DLM, with the configuration just described, in two case studies with challenging conditions. The method is shown to plausibly reproduce spatial variations of the diurnal thermal cycle, including the build-up of a basin-scale temperature inversion and its gradual (diurnal) variation over the course of several days. The case study also shows that the model successfully disentangles the spatio-temporal patterns of the lake-, valley- and CAP-effects from the input data.

Temperature predictions in a high-mountain area are subject to uncertainty that may be relevant to consider in applications. The statistical model employed for TabsH also informs about these uncertainties. We provide this information as a separate dataset, denoted TabsHunc, on the same grid and at the same time points as TabsH. TabsHunc is a measure of the standard deviation of the distribution of the prediction error. It should be noted that TabsHunc is about errors in the prediction of the true value and, hence, it is not about the distribution of potential measurements which would also involve measurements errors. An example field of TabsHunc is depicted in Figure 2. It shows that the magnitude of the prediction error strongly depends on distance from measurement sites.

The digital elevation model (DEM) used to construct TabsH is from the SRTM (1-km grid, Farr et al. 2007). Some manual adjustments have been made to avoid valley cut-offs as a result of the finite resolution. The DEM is available with the datasets.

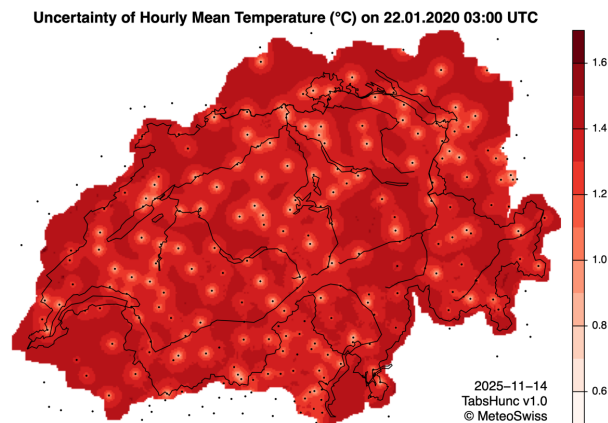


Figure 2: TabsHunc for 22. January 2020, 3:00 UTC. The values quantify one standard deviation of the prediction error of TabsH, shown in Figure 1. Values are given in °C.

Target users

The hourly time resolution offered in TabsH provides an explicit description of the diurnal variation of temperature, not covered in the daily data product (TabsD). It is therefore suitable for all kinds of applications that require detail in the temporal evolution. There is a wide range of environmental processes and pertinent modeling applications that depend on sub-daily resolution. Examples are soil-atmosphere water fluxes (e.g. evaporation, snow/rain distinction), the evolution of snow covers (e.g. melting), the growth of economic plants (crops, pasture), the mass balance of glaciers, etc. Similar requirements are met in socio-economic sectors such as in health (heat stress), solar power production (efficiency of photovoltaic panels) and engineering (building design). TabsH permits to model the diurnal thermal cycle explicitly and, hence, allows for a more physical rather than parameterized representation of processes.

The spatially complete analysis also provides a valuable reference for the evaluation of model-based temperature forecasts, and high-resolution climate models. Owing to the hourly resolution, such activities may also address the representation of extreme weather conditions

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in numerical models, such as heat waves and related soil drought, the thermal imprints of synoptic fronts, foehn, etc.

A major limitation for applications of TabsH is its short temporal extent. Seven years are rather limited for applications regarding interannual climate variations, climate monitoring, or model evaluation beyond case studies. An extension of TabsH further into the past would be required to facilitate such applications.

Accuracy and interpretation

Despite the specific design of TabsH for the target area and the numerous observations included, its estimates at non-instrumented locations are subject to errors, which are crucial to consider in applications of the data products.

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

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, or missed altogether. An example of such patterns are local-scale wind systems, like the Schöllenen wind in Göschenen, associated with very local thermal anomalies of large amplitude (see e.g. section 4.3 of Frey & Frei 2025).

Interpolation uncertainty: The interpolation accuracy has been calculated by leave-one-out crossvalidation over a 2.5-year period. The results are shown in Figure 3 below. The errors have pronounced diurnal and seasonal patterns, that vary by geographic sub-region.

In the diurnal cycle (Figure 3a), the mean absolute error (MAE) is generally somewhat larger at night than during the day. At night, the MAE reaches values of around 0.8°C in the flatland (green solid line in Figure 3a), 1.0°C in high-mountain locations (red and blue solid lines), and up to 1.2°C in mountain valleys that are strongly affected by CAP (purple solid line). During the day, the MAE is about 0.5°C in the flatland (green solid line), 0.8°C at high-mountain locations (red and blue solid lines), and 1.0°C in mountain valleys (purple solid line). Predictions generally have small biases (mean errors). Notable exceptions are mountaintop locations, where the diurnal cycle is overestimated (red dashed line), and mountain valleys, where predictions are warm-biased (purple dashed line), due to an underestimation of the CAP effect.

In the annual cycle (Figure 3b), the mean absolute error (MAE) is largest in winter and ranges from 0.8°C over the flatland (green solid line) to 1.1°C over the Alps (red solid line). Particularly large errors are found in mountain valleys (purple solid line, MAE up to 1.5°C), mostly due to CAP in these environments, which is underestimated (warm bias shown by the purple, dashed line). In all other seasons, interpolation errors are smaller and attain values around 0.6°C over the flatland (green line), 0.9°C over the Alps (red and blue lines) and 1.0°C in mountain valleys (purple line). Apart from valley locations (purple, dashed line), predictions have small biases in the annual cycle.

It is important to note that values in Figure 3 describe mean errors, suggesting that TabsH is quite accurate on average. In certain cases, however, the errors can be more substantial. In winter, about 10% of the absolute errors in the cross-validation turn out to be larger than 3.1°C

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in mountain valleys and 1.6°C in the flatland. In summer, the quantiles are lower, about 2.1°C in valleys and 1.4°C in the flatland.

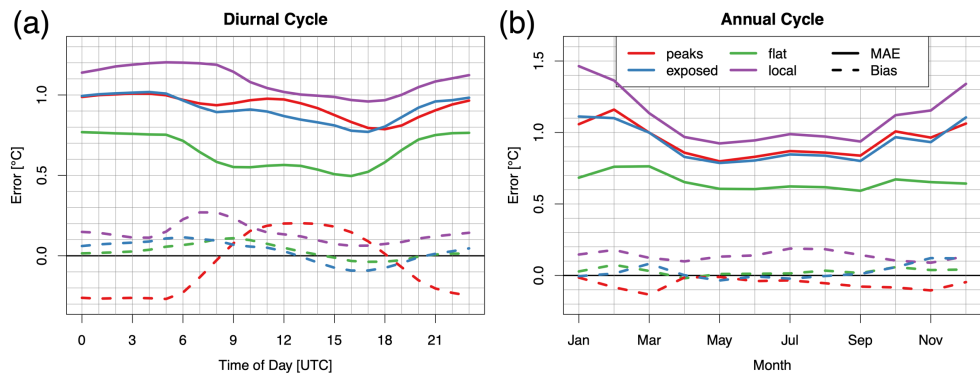


Figure 3: Error statistics of TabsH, estimated from a cross-validation. Shown are the diurnal (panel a) and annual cycles (panel b) of the mean absolute error (solid lines) and the bias (mean error, dashed lines). The results are stratified according to different groups of stations, sharing similar microclimatic environments. Group “peaks” (red) encompasses stations situated on mountaintops at high and medium elevations, that are mostly influenced by the free troposphere. Group “exposed” (blue) contains stations on slopes and ridges at high and medium elevations, also strongly exposed to larger-scale winds. Group “flat” (green) encompasses stations at low elevations, surrounded by flat and hilly terrain, mostly in the Swiss Plateau. Finally, group “local” (purple) contains stations on valley floors and lake shores that are strongly affected by local-scale phenomena such as cold-air pooling and lake effects.

Related products

TabsD / TabsM / TabsY / TminD / TminM / TminY / TmaxD / TmaxM / TmaxY: Similar to hourly mean temperatures but for the daily / monthly / yearly mean and extremes of 2m-temperature. (See Frei 2014 for method detail.) There is no strict consistency between the datasets in the sense that averaging hourly analyses does not exactly reproduce daily, monthly or yearly analyses. If daily/monthly/yearly resolution is sufficient, it is recommended to work with the analyses for coarser time resolution.

CombiPrecip: Similar to hourly mean temperatures, but for precipitation.

Grid structures

TabsH is available in the following grid structures:

ch01h.swiss.lv95 (1-km grid, swiss coordinates, domain of hydrological Switzerland)

an analysis on a 1.1-km grid of COSMO (rotated lon-lat) can be provided upon request

Versions

Current version: TabsH v1.0

Previous versions: none

Update cycle

Currently, the data set is static. No updates are planned at present. An extension further into the past, or an operational continuation in near-real time may be considered in the future, but this would require resources.

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