Schweizerische Eidgenossenschaft
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Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Documentation of MeteoSwiss Grid-Data Products

Monthly Temperature and Precipitation Reconstructions

|T / R| rec |abs / anom8110| |M / Y| |1961 / 1901 / 1864|

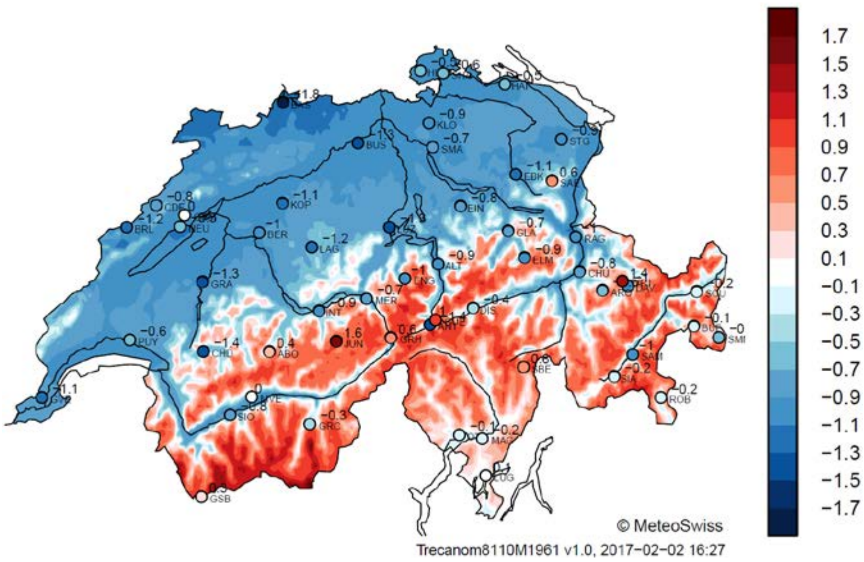

Figure 1: Monthly temperature anomaly (from period 1981-2010) (°C) for October 1962.

Product: Trecanom8110M1961.

Products overview

Product name	Parameter	Value	Aggregation	Starting year
TrecabsM1961	Temperature	Absolute	Monthly	1961
TrecabsM1901	Temperature	Absolute	Monthly	1901
TrecabsM1864	Temperature	Absolute	Monthly	1864
TrecabsY1961	Temperature	Absolute	Yearly	1961
TrecabsY1901	Temperature	Absolute	Yearly	1901
TrecabsY1864	Temperature	Absolute	Yearly	1864
Trecanom8110M1961	Temperature	Anomaly to period 81-10	Monthly	1961
Trecanom8110M1901	Temperature	Anomaly to period 81-10	Monthly	1901
Trecanom8110M1864	Temperature	Anomaly to period 81-10	Monthly	1864
Trecanom8110Y1961	Temperature	Anomaly to period 81-10	Yearly	1961
Trecanom8110Y1901	Temperature	Anomaly to period 81-10	Yearly	1901
Trecanom8110Y1864	Temperature	Anomaly to period 81-10	Yearly	1864
RrecabsM1961	Precipitation	Absolute	Monthly	1961
RrecabsM1901	Precipitation	Absolute	Monthly	1901
RrecabsM1864	Precipitation	Absolute	Monthly	1864
RrecabsY1961	Precipitation	Absolute	Yearly	1961
RrecabsY1901	Precipitation	Absolute	Yearly	1901
RrecabsY1864	Precipitation	Absolute	Yearly	1864
Rrecanom8110M1961	Precipitation	Anomaly to period 81-10	Monthly	1961
Rrecanom8110M1901	Precipitation	Anomaly to period 81-10	Monthly	1901
Rrecanom8110M1864	Precipitation	Anomaly to period 81-10	Monthly	1864
Rrecanom8110Y1961	Precipitation	Anomaly to period 81-10	Yearly	1961
Rrecanom8110Y1901	Precipitation	Anomaly to period 81-10	Yearly	1901
Rrecanom8110Y1864	Precipitation	Anomaly to period 81-10	Yearly	1864

Table 1: Overview of reconstruction products.

Temperature and precipitation reconstructions

Variables

Monthly and yearly mean temperature (“T” in the product nomenclature) or precipitation sum (“R”). Temperature in degrees Celsius, precipitation in millimeters (equivalent to liters per square meter). Available as absolute values (“abs”) and anomalies (“anom”). Anomalies are the difference of surface mean temperature or the fraction of actual precipitation over mean precipitation in 1981-2010 (norm period).

Application

Climate monitoring, trend calculation, analyses over a long time period, applications requiring high standards in temporal consistency. These products are the only gridded datasets, for temperature and precipitation, that extend beyond 1961.

Overview

The reconstruction products are spatial analyses of monthly and yearly temperature and precipitation covering the entire territory of Switzerland and extending over a multi-decadal period (1961-present) or over more than a century (1901-present and 1867-present). Compared to other products, such as TabsM or RhiresM, where the focus is placed on spatial detail and high local accuracy when exploiting all available (i.e. automatic and manual non-realtime) measurements, the reconstruction products are characterized by high temporal consistency. To this end, only homogeneous stations are used, without gaps over the whole period to guarantee a fully constant network of input data. The small number of stations satisfying these requirements precludes classical interpolation commonly used in spatial climatology. Here, a reconstruction method, called RSOI, is adopted (see section “method”). The products described here are presented in detail in Isotta et al. (2019).

Data base

The reconstruction products are based on monthly mean temperature and precipitation totals measured at the high-resolution station network of MeteoSwiss. The reconstructions make use of gridded datasets previously generated using all quality checked station measurements available for a particular month (TanomM and RhiresM). In addition, homogenized time series (Begert et al. 2005) are considered, which are fully continuous over the whole period targeted with the respective product (see details in the “method” section). The station locations and numbers are shown in Figure 2 and Table 2. For a few time series, gaps in the time series have been carefully filled using representative stations in the surroundings.

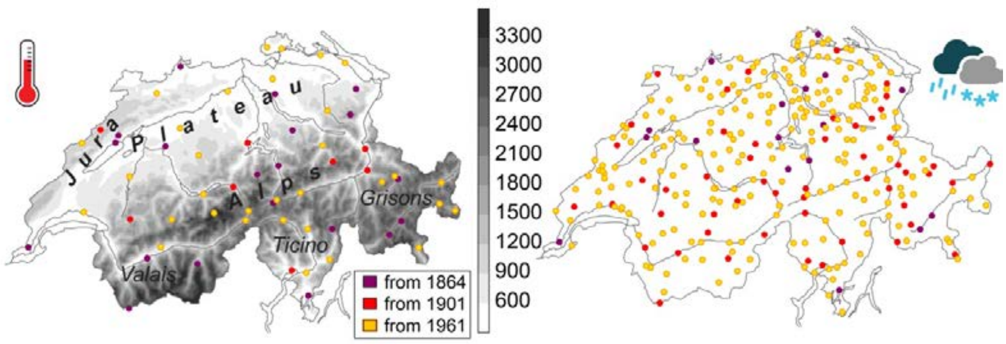

Figure 2. Location of stations with continuous and homogeneity-tested data series since 1864 (violet), 1901 (red and violet) and 1961 (orange, red and violet). Left panel is for temperature, right panel for precipitation. Grey shading in the left panel shows the topography (altitude in meters).

Period		
1864-2017	20	17
1901-2017	28	69
1961-2017	60	300

Table 2. Number of homogeneous and fully continuous temperature (second column) and precipitation (third column) time series available during three reconstruction periods (first column).

Method

The temperature/precipitation analyses are obtained by applying a statistical reconstruction technique, the "Reduced Space Optimal Interpolation (RSOI)". In short, RSOI represents fields in a transformed state space, spanned by a truncated set of principal component loadings (the reduced space), and estimates a linear model between that representation and the long-term data, such that the expected reconstruction error is minimized (optimal interpolation). Technically, the procedure involves a Principal Component Analysis (PCA) of the high-resolution grid dataset, and an Optimal Interpolation (OI) of PCA scores from long-term station data. These steps are further explained in the following. More technical descriptions of RSOI are given in Kaplan et al. (1997), Schmidli et al. (2001) and Schiemann et al. (2010).

PCA step. The gridded datasets TanomM for temperature and Rhires for precipitation are subjected to a PCA using the variance-covariance matrix (e.g. Wilks 2005) over the calibration period defined as 1981–2010. The resulting ordered set of PC loadings represents spatial patterns of variability. Only the leading vectors of the principal-components basis are retained (truncation), which reduces the dimensionality of the data space describing the temperature and precipitation fields. More than 95% of the variability is explained by the subset of principal components retained.

For precipitation, a square-root transformation is applied to the data beforehand, in order to reduce the skewness. For temperature, the PCA is calculated from anomalies (deviations from the calendar-month means of the period 1981-2010), in order to separate the annual cycle from the actual reconstruction.

OI step: The reconstruction is modelled as a linear relationship between the observations at the long-term stations and the coordinates of the reconstructed field in the reduced space (PC scores). The model (matrix) is estimated by reference to a reconstruction error, that involves errors in local representativity of the long-term measurements (attribution of stations to grid cells) and errors for the truncated representation of the reconstruction (e.g. Schiemann et al. 2010). The error covariance matrix is estimated from data over a calibration period (1981-2010) when both, high-resolution grids and long-term station data, are jointly available. The OI cost function also involves a penalty for variance in the higher order PCA scores in order to improve robustness and to balance the information flow between areas of different station density (Kaplan et al. 1997). Once estimated, the linear relationship is applied to the long-term station data, to yield reconstruction fields that can be considered best estimates given the empirical error covariance in the calibration period.

Temperature and precipitation reconstructions

Target users The reconstruction products meet needs for long-term spatial climate data desired for climate and environmental monitoring such as in glaciology, hydrology, and climate change studies. The long period covered by the datasets, more than 150 years, is attractive for analyses in periods when no other spatial datasets can be provided by MeteoSwiss.

Accuracy and interpretation RSOI permits to recover spatial patterns that are not explicitly resolved by the coarse density of long-term climate stations. It combines long-term measurements with statistical information (i.e. the spatial covariance structure) from a high-resolution analysis. The RSOI method is targeted for regions with a complex orography, such as the Alps, where temperature and precipitation fields show anomaly patterns that are geographically locked.

The following issues should be considered when interpreting the reconstruction fields:

- Grid spacing vs. effective resolution: Despite the ability to recover spatial patterns not explicitly resolved, the effective resolution of the reconstruction datasets is coarser than in datasets constructed with high-resolution station data (TabsM, TabsY and RhiresM, RhiresY). Our assessment reveals that the loss in detail may be relatively small, except for reconstructions starting in 1864. Clearly, the km-scale grid spacing does not imply that these scales are resolved. As for products like TabsM and RhiresM, the user should be careful in relying on estimates at single or very few grid points. In particular, the reconstructions are not suitable to obtain statistics on local extremes.

  There is a pronounced underrepresentation of stations at higher altitudes and in complex topographic conditions, especially for reconstructions starting in 1864 (see Table 2, for temperature the biggest reduction happens already in the products starting from 1901 compared to the one from 1961). The strong reduction and the very small number of stations is particularly dramatic for precipitation, which for a spatial analysis needs more measurements compared to temperature due to its reduced representativeness and high variability in space.

  Small-scale effects such as urban heat islands and local cold pools are not reproduced in the present datasets. In-situ measurements for these expositions are mostly missing.

- Interpolation errors: a leave-one-out cross-validation was calculated to estimate interpolation errors. This reveals the magnitude of errors for the case when values at a gridpoint are interpreted as local point estimates. In fact, such interpretation should rather be avoided. But these numbers serve as conservative error measures when the analyses are interpreted as local averages.
  For temperature, the mean absolute error (MAE) in cross-validation experiments is typically around 0.3°C. The error is larger in winter, when gridding is more complex due to inversions and higher spatial variability.
  For precipitation, MAE is around 10% with strong variations between regions and time as the monthly precipitation sum in Switzerland (10-400 mm/month). Analogue to temperature, the cross-validation errors increase for stations isolated (horizontally or in elevation) from other measurement devices or in special climatological regions. The highest values are found in summer, when the monthly sums are higher and convection complicates the precipitation fields compared to seasons dominated by stratiform precipitation.

- In general, higher uncertainties are to expect in regions of complex topography, very low station density or areas with a special climatology (e.g. cold pools). For temperature, larger errors are to be expected along the northern rim of the Alps, in the Valais and northern Ticino. For precipitation, regions with relatively larger errors are the southern parts of the Alps (Valais, Ticino, part of Grisons). The reconstruction performance depends from month to month depending on the observed weather complexity and vicinity to recurring patterns.

- Temporal homogeneity: The method used for the reconstructions focuses on high temporal consistency. The products are suitable for studies on long-term variations (e.g. trends).

- For precipitation, there was no attempt to correct for systematic measurement errors (underestimation especially in wind exposed stations in presence of strong wind and for snowfall, see product document of RhiresD).

- The availability of reconstruction products with three different starting dates permits to benefit from the improvement of network density over time. Thus, the reconstructions covering a shorter period are generally more accurate than the longer ones. The differences are found to be relatively small over the Swiss plateau, but more substantial in regions of complex topography and regions with low station density (Valais and Ticino). We recommend users to use the shortest dataset covering the entire period of interest. A mixing of the different products should be avoided as this violated temporal consistency (e.g. trend calculation with a dataset where TrecabsM1901 from 1901 to 1960 is mixed with TrecabsM1961 from 1961 onward).

For more information please refer to Isotta et al. (2019).

Related products

If time consistency is not of major relevance, or if the period of interest starts after 1961, or if daily fields are required, the original temperature (TabsD, TabsM, TabsY) and precipitation analyses (RhiresD, RhiresM, RhiresY), or the respective anomaly datasets (e.g. TanomM8110, RanomM8110), are likely more appropriated, because of a better spatial representativity owing to the higher station density.

Grid structures

The monthly and yearly temperature and precipitation reconstructions are available in the following grid structure: ch02.lonlat

Versions

Current version: v1.0

Previous versions: none

Production cycle

The monthly fields are produced typically on the 25th of the following month to include all available manual measurements and to await all the regular processing for data quality. The yearly fields are available typically on the 25th of January of the following year. All products are fully updated if major changes are made in the homogenized long time series.

References

Begert M, Schlegel T, Kirchhofer W. 2005. Homogeneous temperature and precipitation series of Switzerland from 1864 to 2000. International Journal of Climatology 25: 65-80.

Isotta FA, Begert M, Frei C. 2019. Long-term consistent monthly temperature and precipitation grid datasets for Switzerland over the past 150 years. In preparation.

Kaplan A, Kushnir Y, Cane MA, Blumenthal MB. 1997. Reduced space optimal analysis for historical data sets: 136 years of Atlantic sea surface temperatures. Journal of Geophysical Research 102: 835–860.

Schiemann R, Liniger MA, Frei C. 2007. Reduced space optimal interpolation of daily rain gauge precipitation in Switzerland. Journal of Geophysical Research 115. DOI: 10.1029/2009JD013047

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Schmidli J, Frei C, Schär C. 2001. Reconstruction of mesoscale precipitation fields from sparse observations in complex terrain. Journal of Climate 14: 3289–3306.

Schmidli J, Schmutz C, Frei C, Wanner H, Schar C. 2002. Mesoscale precipitation variability in the region of the European Alps during the 20th century. International Journal of Climatology, 22: 1049-1074.

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