Documentation of MeteoSwiss Grid-Data Products

Daily Precipitation (final analysis): RhiresD

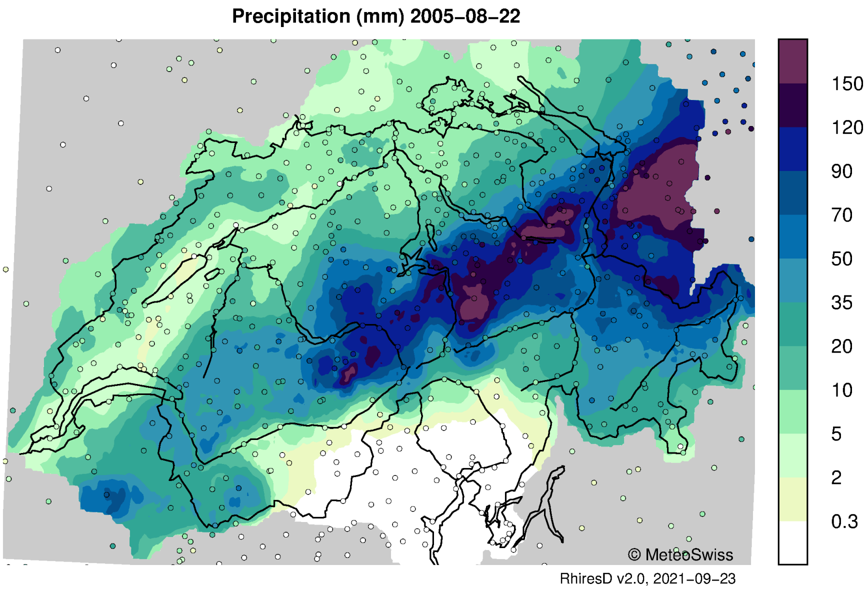

Figure 1: Daily precipitation total (mm) for 22. August 2005. Analysis derived from rain-gauge measurements.

Variable

Daily precipitation on day *D*, corresponding to rainfall and snowfall water equivalent accumulated from 06:00 UTC of day *D* to 06:00 UTC of day *D+1*. In millimeters (equivalent to liters per square meter).

Application

Water resources and hydropower management. Hydrology, agriculture, engineering and tourism. Natural hazards prevention. Climate monitoring. Climate change downscaling.

Overview

RhiresD is a spatial analysis of daily precipitation over *hydrological Switzerland*, encompassing all locations from where surface waters can drain to locations within the national border. Temporally, the analysis extends over a multi-decadal period (1961-present). It provides detailed spatial information and high accuracy by exploiting all available rain-gauge measurements (typically 430 within, and 220 outside Switzerland each day). RhiresD serves a broad range of monitoring and planning tasks and as input into quantitative models of environmental processes. The data product is available with a delay of 3-6 weeks.

Data base

RhiresD is based on daily precipitation totals measured at the high-resolution rain-gauge networks from MeteoSwiss and from weather services in the neighboring countries. The analysis uses all measurements available for a particular day to ensure maximum effective resolution and accuracy. As a consequence, the observational base varies from day to day.

In terms of geographical distribution, the rain-gauge stations within the national border are evenly spaced in the horizontal (see e.g. Fig. 1). However, there is a clear imbalance in the vertical, with regions above 1200 mMSL being comparatively under-represented (see e.g. Frei and Schär 1998, Konzelmann et al. 2007). Outside the swiss border, the station density is heterogenous, with relatively dense coverage in Germany, Austria and the Toce- and Aosta vallies in Italy, compared to coarser coverage over France and Lombardia.

In terms of temporal distribution, the number of stations within Switzerland varies moderatly. There are 420 in the early 1960ies, increasing to about 520 in the mid 1970ies and decreasing thereafter, reaching approx. 430 after 2005.

Outside Switzerland, the station networks vary substantially. Back until about 2005, the density is reasonably stable, but it becomes gradually coarser further back in time. Before 1992, data for the Toce and Aosta valleys is missing altogether and for the section over France it is very coarse. To avoid undue extrapolation, **the Italian and French parts of the domain have been masked out (i.e., set to NA) before 1992**. Finally, before 1971, the data density is less than a fifth of that in Switzerland, also over the German and Austrian sectors, but the analysis domain was not further restricted.

The majority of the rain gauges operated in Switzerland between 1961 and 1980 were manual Hellmann type gauges with an orifice of 200 cm^2 positioned 1.5 m above ground. Starting around 1980, manual gauges have been converted continuously into automatic gauges (tipping buckets and weighing gauges), which make up almost 60% of all gauges today. Data from neighboring countries is mostly from automatic measurements after 1992.

As regards the quality standards, data from within Switzerland is systematically checked for gross errors and filtered accordingly. For data outside the national border, the quality standard is inferior because of the real time nature of this data, and residual gross errors are to be exptected.

Method

The precipitation analysis for day D is obtained in several steps: (1) Spatial interpolation of the climatological mean precipitation measurements for the calendar month of day D (reference period 1971-1990); (2) Calculation of relative anomalies of station measurements on D with respect to the climatological mean from step 1; (3) Spatial interpolation of relative anomalies; (4) Multiplication of the resulting anomaly field with the climatological mean field.

The interpolation in step 1 adopts regionally varying precipitation – topography relationships, estimated by local weighted linear regression. A version of the PRISM algorithm by Daly et al. (1994, 2002) is applied and adjusted for the Alpine region (Schwarb et al. 2000, Schwarb et al. 2001). The purpose of using a climatological reference field for the interpolation of daily precipitation is to reduce the risk of systematic errors due to the under-representation of measurement stations at high elevations (Widmann and Bretherton 2000).

For version “v2.0” of the data product a manual adjustment has been applied to the original climatological background field of Schwarb et al. (2001) in order to amend unrealistically wet conditions in the region of the Jungfrau massif. The wet anomaly there was reduced by 23% for the annual total (25% in summer, 13% in winter) centered on the massif and gradually decreasing to zero over a radius of 25 km.

The interpolation in step 3 adopts a weighting scheme, which emphasizes the contribution of measurements that are close to the analysis point and/or exhibit a high degree of directional isolation in the neighborhood of the analysis point. For this purpose, a modified version of the SYMAP algorithm by Shepard (1984) is employed. Some detail of the interpolation scheme is described in section 4.1 of Frei et al. (2006) and in Frei and Schär (1998). For version "v2.0" of the analysis, a further adjustment has been made to the radial weighting scheme to better cope with the more highly variable station density over the extended analysis domain.

Target users

RhiresD addresses needs for environmental planning and monitoring in a broad range of fields (water resources, hydrology, agriculture, hydropower, etc.). The daily time resolution together with the long-term coverage permits for statistical analyses on the frequency of regional heavy precipitation, and, in combination with runoff models, the occurrence of extreme water levels in lakes and high stream flow conditions in rivers. RhiresD has been employed in numerous statistical analyses and modelling applications, including the analysis of flooding events (Bezzola and Ruf 2009), the modelling of streamflow (Addor et al. 2014, Fatichi et al. 2015), for snow hydrology and climatology (Jonas 2018, Frei et al. 2018), in geomorphological studies (Leonarduzzi et al. 2017, Costa et al. 2018), for high-resolution climate change scenarios (Peleg et al. 2017, CH2018), and for the evaluation of NWP and climate models (Montesarchio et al. 2014, Voudouri et al. 2017, Bandhauer et al. 2021).

Accuracy and interpretation

The accuracy of RhiresD depends on the accuracy of the underlying rain-gauge measurements and the capability of the interpolation scheme to reproduce precipitation at ungauged locations.

Measurement errors: Measurements by rain gauges are subject to systematic errors. Wind-induced deflection of hydrometeors over the gauge orifice results in an underestimation of true precipitation. The "gauge undercatch" is comparatively larger during episodes with strong wind, or at wind-exposed stations and during weather with small rainfall intensity or with snowfall (Neff 1977, Yang et al. 1999). Sevruk (1985) estimates the systematic measurement error in Switzerland to range from about 4% at low elevations in summer to occasionally more than 40% above 1500 mMSL in winter. RhiresD must therefore be expected to generally underestimate precipitation, particularly during days with snowfall and at wind-exposed locations.

Interpolation errors: The magnitude of interpolation errors depends on how the analyses are interpreted by the user. If gridpoint values are expected to represent local point estimates, interpolation errors are substantial: A "leave one out" cross-validation reveals that the standard error is in the order of a factor of 1.7 for light precipitation (< 20% quantile) and a factor of 1.3 for intense precipitation (> 90% quantile). Errors are slightly larger (smaller) in summer (winter). It is important to note, that there is a general tendency (i.e. a systematic error) to overestimate light and underestimate intense precipitation, which is a consequence of interpolation uncertainty. These conditional biases are a consequence of interpolation uncertainty and they are relatively larger in data sparse areas and in cases of high spatial variation (e.g. a day with convective rainfall). Hence, RhiresD will not properly inform about statistics of heavy point-scale precipitation. If gridpoint values are interpreted as area mean values (e.g. over one or many grid cells), the magnitude of the error is smaller. It is difficult to derive error statistics for this line of interpretation because of the lack of an appropriate evaluation reference. Special uncertainty analyses for cases of intense precipitation suggest that standard errors are in the order of a factor of 1.25 to 1.5, if the estimates are interpreted as 20x20 km^2 area-mean values (Frei and Isotta 2019).

Grid spacing vs. effective resolution: The substantial interpolation error and the conditional bias in the statistics points to the limitations with which small-scale variations can be resolved and statistics at small scales recovered. We expect that the effective resolution of RhiresD is in the order of 15-20 km, likely even coarser in the high mountains and outside Switzerland. This is important to recognize by users. The km-scale grid spacing does not imply that these scales are actually resolved. RhiresD fields are much smoother than real precipitation fields at the nominal km scale. We recommend users to interpret the estimates as area-means over a 250-400 km^2 surrounding, and to not expect RhiresD to represent statistics on local precipitation extremes.

Temporal homogeneity: Temporal variations in the station network (see section *Data base*) invoke climatological inhomogeneities in RhiresD. These can affect long-term variations, especially in high-frequency statistics (e.g. frequency of wet days, exceedance of thresholds). Users requiring better long-term consistency can contact MeteoSwiss to investigate the possibility for a dedicated regional data product that aims at temporal consistency, rather than at spatial resolution.

Reduced quality outside Switzerland: The database available for the analysis outside the Swiss border is less extensive and partly not quality checked. As a result, the quality of the analysis is clearly inferior over these areas, compared to that within the country border. Notably, users must expect considerable smoothing in the fields before 1971 over Germany and Austria, due to the limited station density. Moreover, the analysis happens to show evident gross errors, particularly in wintertime when some of the automatic gauges failed to heat during snowfall.

Related products

RhydchprobD: A probabilistic daily precipitation analysis, based on the same high-resolution rain-gauge network and the same domain, but presented as an ensemble of possible spatial distributions. This product allows to trace interpolation uncertainty into applications (ensemble), it reproduces the statistics of extremes more accurately, and allows interpretation at smaller scales. See Frei & Isotta (2019) for further information.

RprelimD: A preliminary estimate of the distribution of daily precipitation based on a subset of the stations of RhiresD that is available in real time (i.e., with a delay of one day). Methodologically, RprelimD (v3.0) is similar to RhiresD (v2.0), but less accurate and less detailed, due to the smaller observational basis and preliminary data quality status. RprelimD is meant to serve users with a need for real-time daily data. RprelimD is superseded by RhiresD when that becomes available.

RhiresM / RhiresY: Similar to RhiresD but for the monthly / yearly precipitation sum and restricted to the domain within the Swiss country borders. There is no strict consistency between these products. E.g. adding the daily analyses of RhiresD does not reproduce RhiresM exactly. This is due to differences in the underlying measurement data, when stations only cover part of the month. Differences are small in practice.

CPC: An hourly precipitation dataset obtained from a statistical combination of simultaneous radar and rain-gauge measurements. This data product is available in near real-time. Aggregation of CPC over one day does not replicate RhiresD. RhiresD is informed by many more non-automated rain gauges.

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

Daily Precipitation: RhiresD

Grid structures

RhiresD is available in the following grid structures:

ch02h.lonlat, ch01h.swiss.lv95, ch.cosmo1.rotpol, ch.cosmo2.rotpol, ch.cosmo7.rotpol (analyses on cosmo grids are provided upon special request only)

Versions

v2.0: The current operational version of RhiresD

v1.0: This version was operational for many years until 2021. It was available for the area within the country borders only, has used a slightly different radial weighting scheme compared to v2.0, and has suffered an unrealistic moist anomaly in the Jungfrau region.

Update cycle

RhiresD is updated once every month to include all available manual measurements and the results of the regular processing of data quality control. The update for all daily fields of a month is available typically on the 25th of the following month.

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