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Documentation of MeteoSwiss Grid-Data Products

Daily Precipitation Ensemble: RhydchprobD

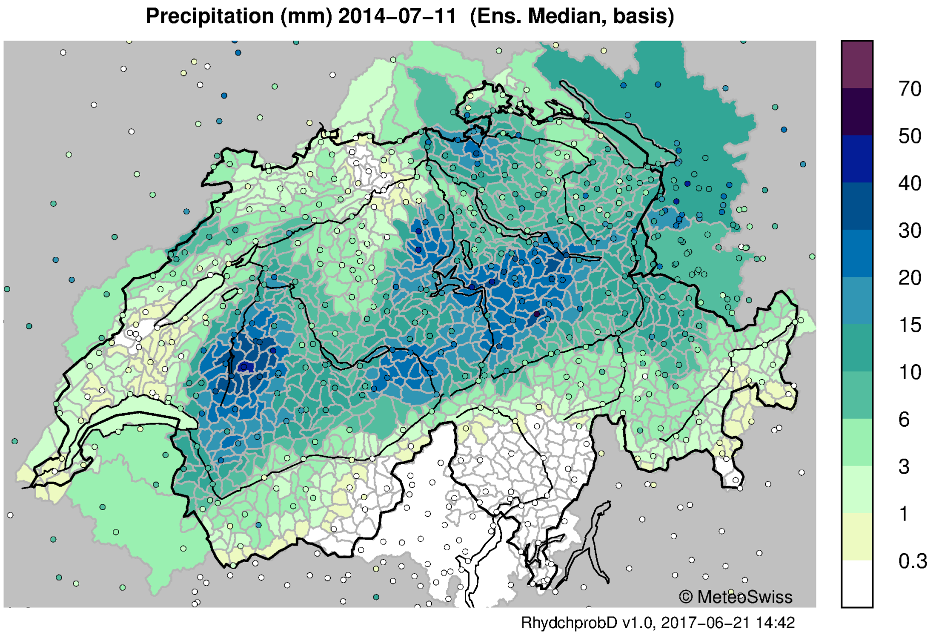

Figure 1: Daily precipitation total (mm) for 11. July 2014. Median of an ensemble estimate of precipitation averaged over hydrological units (Basis regions) in and around Switzerland.

Variable

Daily precipitation on day *D* averaged over hydrological units. The variable represents the sum of rain 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

Hydrology, soil water and snow modelling. Flood protection planning. Water resources and hydropower management. Evaluation of weather prediction and climate models.

Overview

RhydchprobD is a probabilistic analysis of area mean daily precipitation for hydrological terrain units in Switzerland and catchments near the Swiss border. The analysis is provided as a 50-member ensemble, describing the uncertainty of the estimates, related to the limited density of the underlying rain-gauge measurements. The data product spans the period from 1961 till present. It is devoted to all sorts of applications where quantitative tracing of uncertainties and probabilistic assessment of results is desired.

Data base

RhydchprobD is based on daily precipitation totals measured at the rain-gauge network of MeteoSwiss and at near-border stations of authorities abroad. All quality checked station measurements available for a particular day enter into the product. Within Switzerland the station base varies slightly from day to day with a gradual increase over the years (see also product RhiresD). In the near border area of Austria, France, and Germany the station coverage increases by a factor of two to five between 1961-2010. For Northern Italy data is only available since 2010.

The geographical distribution of rain-gauge stations in Switzerland and in regions abroad shows an imbalance in the vertical distribution, with regions above 1200 mMSL being comparatively under-represented (see e.g. Frei and Schär 1998, Konzelmann et al. 2007).

Between 1961-1980 rain gauges were primarily of the manual Hellmann type. Since 1980 stations have gradually been converted to automatic operation, using tipping-bucket or weighting gauges. In 2010, about half of the gauges in Switzerland and Austria were automatic. Germany, France and Northern Italy operate fully automatic networks today.

Method

The probabilistic dataset distinguishes from conventional spatial analyses in two fundamental ways. Firstly, it provides precipitation estimates for averages over well-defined geographical units (a hierarchical hydrological partitioning of Switzerland, Breinlinger et al. 1992, BAFU 2012), instead of points on a regular grid. Secondly, these estimates are provided as an ensemble of possible realizations. The advantage over conventional “single estimates” is that the ensemble explicitly quantifies uncertainties arising from the limited sampling of the spatial distribution by the station network. The ensemble permits a user to trace these uncertainties into her application.

The probabilistic estimates are constructed separately for each day and individually for ten contiguous sub-regions of the domain. For each of these processing units, the method assumes that the true (unknown) distribution of precipitation is a realization of a trans-Gaussian random field (sort of a random number generator of fields, Schabenberger and Gotway 2005), and that the rain-gauge measurements are samples of that field at the location of the stations. Under these assumptions, the measurements are used, firstly, to derive information on the structural parameters of the stipulated field, such as the variance and spatial correlation structure. This is accomplished via Bayesian inference using Markov-Chain Monte-Carlo sampling (Hoff 2009). Finally, using the samples of model parameters from the joint posterior, trans-Gaussian random fields are simulated conditional on the measurements at the stations. The simulated fields are represented on a regular 1-km grid. They describe possible point measurements that could have been taken at the nodes of the grid, conditional on the actual measurements made at the stations. Area mean values over the hydrological units are then determined by averaging the points of the grid within the unit. 50 simulated fields provide the ensemble of the area averages. Although the primary result of the procedure is the ensemble of area averages, the simulations on the grid are also archived and can be made available for users requiring higher resolution.

Illustrations and detail of the ensemble method are provided in Frei and Isotta (2019). The paper illustrates that the results of the procedure plausibly describe variations in the magnitude of uncertainty in response to the nature of rainfall (e.g. convective versus stratiform days), the density of the measurement network and the size of catchments. Independent evaluation suggests that the ensemble is reasonably reliable, i.e. quasi-measurements of area mean precipitation in a test region are contained within the range of ensemble members at the expected frequency.

Daily Precipitation Ensemble: RhydchprobD

Target users

The ensemble precipitation products are developed for applications and modelling tasks concerned with the hydrosphere. More specifically, for use cases where results are expected to be sensitive to the accuracy of the precipitation input data and, hence, where explicit tracing of the pertinent uncertainties is desirable. The development of flood forecasting tools, for example, where uncertainty of past rainfall is to be integrated. Or, the evaluation of high-resolution weather forecasting and climate models, where representativity errors of conventional single estimates are becoming substantial at high resolution (e.g. Tustison et al. 2001, Göber et al. 2008). The ensemble products are, however, not recommended for users with high requirements in long-term consistency (e.g. trend analyses) or applications relying on accurate climatology (long-term mean values) at high altitudes (see below).

Accuracy and interpretation

The ensemble analysis builds on a stochastic model that involves simplifying assumptions with limited representativity for precipitation fields in nature. The limitations are related to the non-existence and/or excessive computational demands of more realistic models. There are implications for the interpretation and application of results by the user:

The ensemble encapsulates uncertainties related to the density and spatial distribution of the underlying measurement network. However, it does not consider uncertainties due to (systematic or random) measurement errors. As a consequence, the ensemble spread tends to underestimate the effective uncertainty. The overconfidence can be expected to be larger for small-scale catchments and virtually insignificant at large scale (>1000 km^2). Moreover, the ensemble tends to be biased towards dry conditions, most so on days with snowfall and at high altitudes (see Sevruk 1985). The documentation of product RhiresD lists estimates for the expected bias. One of the future extensions of the ensemble technique shall include measurement errors as additional source of uncertainty.

The modelling approach used for the ensemble assumes a spatial covariance structure depending on 2D Euclidean distance alone. There is no modelling component for covariance patterns related to topographic features (e.g. elevation, slope, wind exposition). As a consequence, the ensemble dataset does not reproduce precipitation-topography relationships at scales below the station network (e.g. Masson and Frei 2016). Such patterns do rarely explain a substantial fraction of the variations in a daily precipitation field, but they are generally significant in describing fields of precipitation aggregated over monthly and longer time scales (Schwarb et al. 2001). Therefore, we do not suggest this dataset for applications where the primary interest is in long-term sums, such as in water balance studies. Temporal aggregations of the ensemble dataset may be subject to biases related to the prominence of stations at low compared to high elevations, which our methodology does not account for. The primary purpose of this data product is to describe precipitation fields and pertinent uncertainties at the daily or event time scale.

Variations in the station network over time and inhomogeneities in the measurement series (e.g. Begert et al. 2005) invoke climatological inhomogeneities in RhydchprobD. These can lead to spurious (i.e. non-climatic) long-term variations in the dataset. Users requiring spatial datasets with high climatological consistency should refer to the dedicated climate monitoring datasets (e.g. RrecabsM1901).

The grid point version of the ensemble dataset is constructed in a fundamentally different way compared to single-estimate grid datasets, such as RhiresD. The grid point values in RhydchprobD should be interpreted as *point* precipitation values, in contrast to RhiresD, which rather represents *area-mean* values over some scale around the grid point (typically the scale defined by the station spacing). The difference in spatial support goes along with markedly different statistical characteristics. Grid point values in RhydchprobD (even if only considering the ensemble median) have much longer tails than the area-representative values in RhiresD. This may have consequences in applications and should be carefully considered by users. Switching from RhiresD to RhydchprobD as input source for a model may require additional adjustments. The advantage of RhydchprobD is that the spatial representativity is well defined (point scale for grid points, catchment area for values over hydrological units) whereas the “effective scale” of RhiresD is a diffuse notion that varies in space and time with the station network.

The construction of RhydchprobD proceeds independently over ten contiguous sub-regions of Switzerland (see Fig. 2) with results being subsequently stitched together to form a country-wide ensemble. The sectorial treatment allows to model regional variations in the statistical characteristics of precipitation across the domain. As a consequence, ensemble members are statistically independent (conditional on observations) across the borders of these calculation regions. E.g. member 23 in region A is not related to member 23 in the adjacent region B. This implies that an application combining results from two (or more) calculation regions will not adequately represent the effective uncertainty. The limitations arising for hydrological applications should be minimal, because the calculation regions are aligned with major river catchments. Also, combining averages over entire calculation regions, is feasible, because the error correlation becomes negligible for larger scale aggregates. For example, an ensemble of the mean over the entire Rhone catchment can be derived by aggregating ensemble members of the two pertinent sub-regions (see Fig. 2). An illegitimate combination is, however, calculating the average (or another arithmetic function) of grid points in a small region (typically less than 1000 km^2) that straddles two or more calculation regions. That combination would underestimate the real uncertainty. It is important that users are aware of this limitation. The definition of calculation regions is provided together with the dataset.

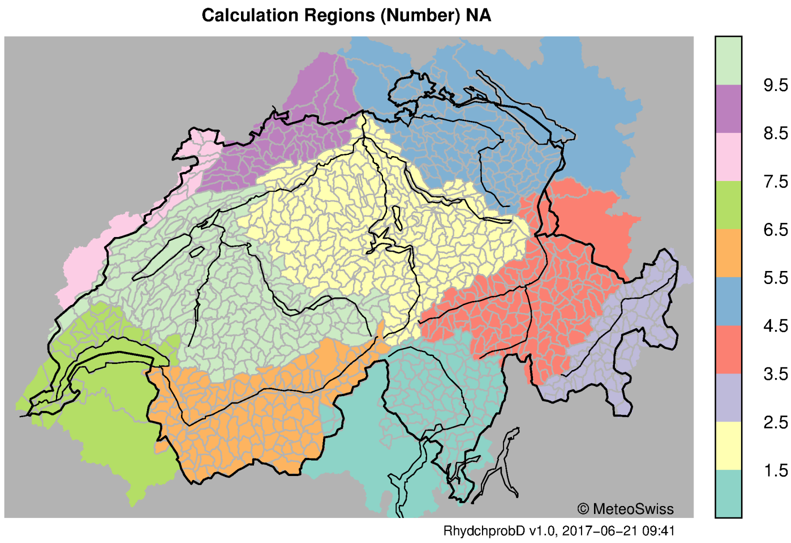

Figure 2: Regional subdivision used for calculating RhydchprobD (calculation regions).

Related products

RwarnchprobD: A similar probabilistic precipitation analysis, but representing area average precipitation over the 159 warn regions in Switzerland.

RprelimD and RhiresD: “Single estimate” grid datasets of daily precipitation for Switzerland, provided on a regular grid. (See the pertinent product documentations.) Note that neglection of climatological precipitation-topography relationships in the production of RhydchprobD will lead to differences with RhiresD.

RapdensD: A similar probabilistic precipitation analysis for the entire Alpine region (see Frei and Isotta 2019), using data from the high-resolution rain-gauge networks of all Alpine countries (Isotta et al. 2014).

Grid structures

RhydchprobD is available in the following grid structure:

ch01h.swisscors

Versions

Current version: RhydchprobD v1.0

Previous versions: none

Update cycle

RhydchprobD is processed on a daily basis exploiting the station data available in near real time. The product is then updated at instances when major blocks of new station data become available. A final processing of all days of a month is run typically on the 25th of the following month, when data amount and quality reaches its (almost) final state.

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