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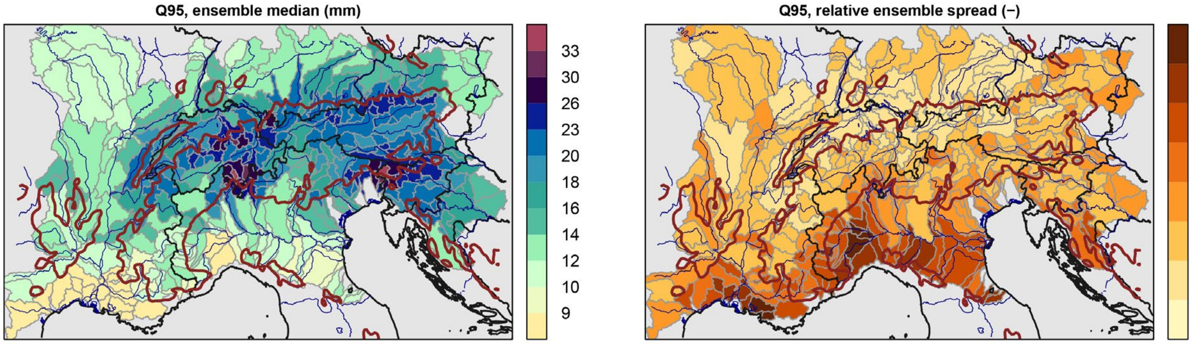
Documentation of MeteoSwiss Grid-Data Products

Alpine Precipitation Ensemble Dataset: APGDEns


Q95, ensemble median (mm)

Q95, relative ensemble spread (−)

Figure 1: 95% quantile of area-mean daily precipitation in summer for hydrological catchments in the Alpine region. Left panel: ensemble median (mm per day). Right panel: relative ensemble spread (-) expressed as the the 90% interquantile range (90%-10%) devided by the ensemble median.

Variable

Area-mean daily precipitation over hydrological units. The variable represents the sum of rain and snowfall (water equivalent) in millimeters (equivalent to liters per square meter).

Application

Environmental modeling in a broad range of fields (hydrology, soil water etc). Water resources and hydropower management. Evaluation of weather prediction and climate models. Trans-national analysis of precipitation events.

Overview

APGDEns is a probabilistic analysis of area mean daily precipitation for catchments in the territory of the European Alps and adjacent flatland regions (4.8-17.5°E / 43-49°N). The analysis is provided as a 100-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 1971 till 2008. It is devoted to all sorts of applications over the European Alps where quantitative tracing of uncertainties and probabilistic assessment of results is desired.

Data base

APGDEns is based, as the Alpine Precipitation Grid Dataset (APGD, see Isotta et al., 2014) on daily precipitation totals (typically from 06 till 06 UTC) measured at the high-resolution rain-gauge stations (more than 8500 in total) from meteorological and hydrological services of six countries (Austria, Croatia, France, Germany, Slovenia and Switzerland) and from nine regional environmental services in Northern Italy. Approximately 5500 measurements are available each day over the 38-year period 1971–2008. The station data was checked for plausibility (spatial consistency of daily values) by an automated quality control procedure. A detailed description of the underlying rain-gauge dataset and analysis method is provided in Isotta et al. (2014).

Method

The probabilistic dataset distinguishes from conventional spatial analyses in two fundamental ways. Firstly, it provides precipitation estimates for averages over well-defined hydrological units, instead of points on a regular grid. The hydrological partitioning is hierarchical and is taken from the European River Catchment Dataset (EEA, 2016). 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 67 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 high-resolution grid of 3-10km, defined separately for each calculation domain, depending on the size of the involved areal units. 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. 100 simulated fields constitute the ensemble of the area averages.

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.

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 high-mountain catchments but is virtually insignificant at large scale (>1000 km^2) over flatland. Moreover, the ensemble tends to be biased towards dry conditions, most so on days with snowfall and at high altitudes (see Sevruk 1985). 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 APGDEns. 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. HISTALP_REC, produced in 2019 in the framework of the COPERNICUS C3Surf Project, see https://surfobs.climate.copernicus.eu/).

The construction of APGDEns proceeds independently over 67 contiguous sub-regions of the Alpine region (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 a region is not related to member 23 in an adjacent region. 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. It is important that users are aware of this limitation. The definition of calculation regions is depicted in Figure 2. Details of it are also provided together with the dataset.

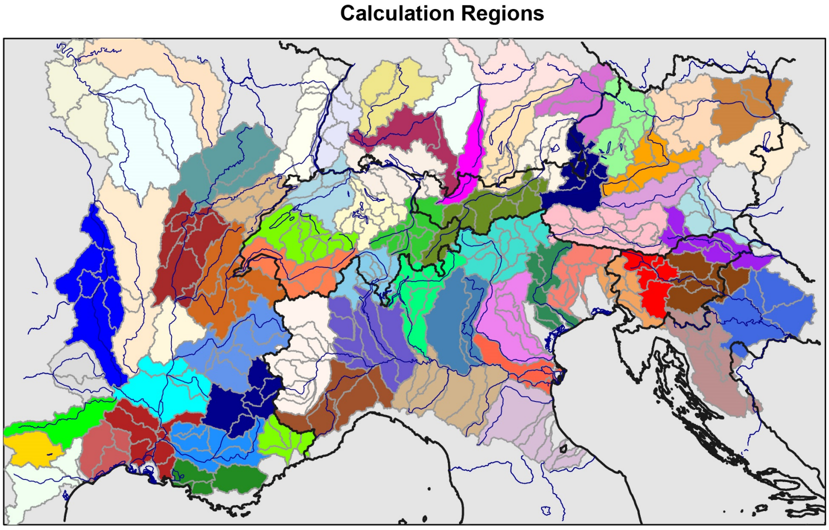


Figure 2: Regional subdivision used for calculating APGDEns (calculation regions).

Related products

APGD: “Single estimate” grid dataset of daily precipitation for the Alpine region, provided on a regular grid (see the pertinent product documentations).

Versions

Current version: APGDEns v1.0

Previous versions: none

Update cycle

APGDEns is not updated in a regular way.

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