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Hourly Precipitation Estimation through Rain-Gauge and Radar: CombiPrecip

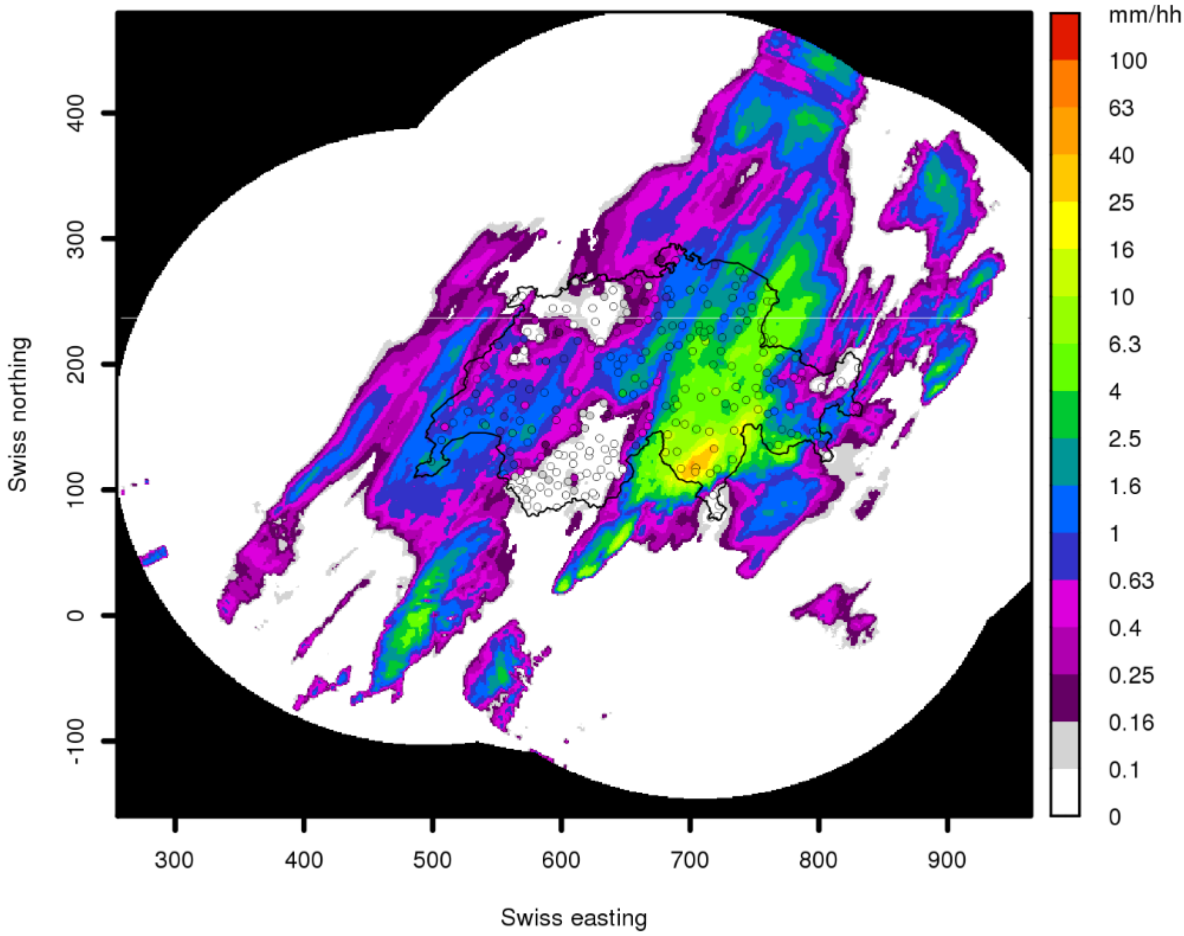

Figure 1: Hourly precipitation total (mm) on 31 August 2017 between 16:00 and 17:00 UTC. The circles represent raingauge measurements of precipitation.

Variable Precipitation for hour *H (UTC)*, corresponding to rainfall accumulated in the interval from *H-1* UTC to *H* UTC. Estimates are in millimeters (equivalent to liters per square meter).

Application Hydrology and rainfall runoff modeling, civil protection, flash flood and debris flow warnings, intervention during flooding, flood prevention, hydropower management, verification of precipitation forecasts of numerical weather prediction models, environmental modeling, agriculture, tourism, and water resources modeling.

Hourly Precipitation: CombiPrecip

Overview

CombiPrecip is a dataset of hourly precipitation fields, which are computed using a geostatistical combination of raingauge measurements and radar estimates. The CombiPrecip fields cover the entire area monitored by the Swiss radars. This extends typically to about 100-150 km away from the Swiss border. The CombiPrecip fields are generated in real-time, with update time 10 minutes, and represent hourly sums (sum over a 60-minutes moving window). They are available since 01.01.2005. A real-time delivery is possible, about 10-15 minutes after the nominal hour. Every week, a reprocessed CombiPrecip product becomes available, in which errors and limitations present in the real-time environment have been taken care of, for instance, rain-gauge values have been subject to an in-depth quality control.

Data base

CombiPrecip combines information from two sources: (a) hourly aggregations of rain-gauge precipitation measurements at the SwissMetNet (SMN) stations and (b) radar precipitation estimates from the radar composite precipitation product (Germann and Joss, 2004, Germann et al., 2006). The temporal resolution of the SMN rain gauges is 10 minutes, and there are currently over 250 automatic stations operating in real-time. The algorithm has the configurable capability to include in its computations rain-gauge measurements from additional networks (other than SMN). The radar estimates result from a series of processing steps and a composition of backscatter measurements made by five weather C-band radars located within Switzerland. The spatial resolution of the radar product is 1 km^2, while its temporal resolution is 5 min.

Method

The hourly precipitation fields are computed using geostatistical techniques, where precipitation is treated as a stochastic process (Creutin et al. 1988; Erdin 2009; Erdin and Frei 2012; Goovaerts 1997; Haberlandt 2007; Krajewski 1987; Schuurmans et al. 2007; Seo et al. 1990). Correlations that characterize the observed precipitation radar and rain-gauge measurements are computed modelled accordingly.

The modeling technique currently employed by CombiPrecip extracts both spatial and temporal information from the observations and models them using co-kriging with external drift. This spatiotemporal approach provides enhanced stability in comparison to geostatistical techniques incorporating spatial data only. As a result, modeling failures are decreased and unrealistic outputs are avoided. This sophistication is justified since is practically attempted to carry out a complex statistical procedure in real-time without human-intervention. The details of the technique are discussed extensively in Sideris et al. 2014.

A relaxation towards the original radar raster for regions outside Switzerland has been introduced into the mechanism. This was motivated by the need for a smooth transition between the geostatistical precipitation estimates within the Swiss area, and the radar estimates far away from Switzerland, where no rain-gauge measurements are available. The effect is achieved through a combination of virtual rain gauges (radar precipitation estimates that pose as rain-gauge measurements) and follow-up filtering, and is described in Sideris et al. 2012.

Target users

CombiPrecip is useful for a number of practical applications where high spatial and temporal resolution in precipitation estimates are of importance, e.g. civil protection, flash flood warnings, intervention during flooding. The archived dataset is also interesting for flood prevention, hydro-power management, agriculture, tourism, validation and research.

Accuracy and interpretation

The accuracy of the product depends significantly on the quality of the input i.e. the raingauge measurements and the radar estimates of precipitation. The rain-gauge data are introduced into the mechanism as a primary variable, the value of which has to be respected within the extent of a variance used to describe errors and micro-variability effects while the radar raster is used as an external trend.

The quality of radar precipitation estimates depends to a large extent on: (a) the distance from the radar, the so-called “range degradation” effect, and (b) the height above sea level of the lowest unshielded beams above the target region, the so-called “radar visibility” (including Earth’s curvature, partial beam shielding by orography and the highly variable in space and time vertical reflectivity profile). The most reliable radar echoes are at short range (say between 3 and 60 km) and at an altitude where most or all hydrometeors are in liquid phase (hence, summer better than winter). A chain of procedures is followed to assure the high quality of radar data: automatic hardware calibration and monitoring, clutter removal, correction for radar visibility, VPR correction, and others.

Rain-gauge measurements, are subject to an extensive quality control (Grüter et al. 2003) before they are used as input of CombiPrecip. This involves: (i) limit tests (comparison to physical and climatological limits), (ii) variability tests (tests of maximum and minimum acceptable variability during a specified time interval), (iii) inter-parameter consistency tests, and (iv) spatial consistency tests (between nearby stations).

Moreover, CombiPrecip checks the rain-gauge measurements for outliers and occasionally excludes measurements that are highly suspicious (either too high or too low).

The combination relies on modeling reasonably well the correlation structure of precipitation a process that takes place through the construction and modeling of a representative variogram. However, the modeled variogram becomes less accurate the smaller the number of wet rain gauges is which affects directly the quality of the outcome.

A quality flag accompanies the CombiPrecip product. This flag combines the information of the quality flag of the radar composite product (which depends on how many of the five radars were operational at the time of the measurement) and the number of the available wet rain gauges. The lowest value of this flag is 0 and the highest is 9. Provided that the number of wet rain gauges is sufficiently large and the original radar coverage is satisfactory the combination map is considered to be reasonably accurate. Low values of the CombiPrecip quality flag do not signify necessarily that the product is wrong, but they aim at informing the client on the level of confidence he/she should have on this product.

CombiPrecip is particularly adequate for observing widespread and long lasting precipitations events, whereas situations characterized by very small and isolated precipitations cells that might not be resolved by the ground based rain-gauge network, are to be evaluated with care.

Tests over several individual cases different in nature, but also over extensive periods of time suggest that the overall bias of the cross-validated results produced by CombiPrecip, is very close to zero (Erdin 2011; Keller 2012; Willi et al. 2011). Moreover, there is a sizeable improvement on numerous other skill scores like the root-mean-squared-error (RMSE), the Hanssen-Kuipers discriminant (HK), and the scatter, but this improvement depends on factors like the weather situation (e.g. convective or not-convective situation), the season or the region in question. A multi-year validation based on cross-validation of hourly amounts of summer precipitation products evaluated in the same 68 sites during six two-year periods provides the following results regarding bias and scatter in dB:

Bias

Product	2005-2006	2007-2008	2009-2010	2012-2013	2014-2015	2016-2017
Radar-only	+0..8±0.40	+0.1±0.44	+0.5±0.77	-0.87±0.66	-0.0±0.96	+0.1±0.32
CombiPrecip	+0.0±0.10	-0.0±0.16	+0.0±0.51	+0.4±0.20	-0.3±0.27	-0.2±0.13

Scatter

Product	2005-2006	2007-2008	2009-2010	2012-2013	2014-2015	2016-2017
Radar-only	3.1±0.12	3.0±0.15	3.0±0.15	3.0±0.15	2.9±0.25	2.7±0.04
CombiPrecip	2.5±0.16	2.4±0.13	2.4±0.10	2.4±0.13	2.3±0.11	2.0±0.07

Finally, it has to be mentioned that the uncertainty of the rain-gauge-radar combination process drops with increasing distance from the rain-gauge locations. This situation does not affect significantly the interior of Switzerland since this is monitored sufficiently well by rain gauges, but it does affect the region outside the Swiss border. Understandably, in very large distances from the border the confidence of the combination estimation is no better than the confidence in the original radar product. For this reason, an algorithm complements the typical modeling-estimation geostatistical scheme, by relaxing in a continuous fashion the combination output towards the original radar map as distance from rain gauges increases. This solution provides conceptually the best possible precipitation map within and nearby Switzerland (combination), and far from Switzerland (radar).

Related products

Radar PRECIP: Original radar precipitation estimates. This product is continuously updated, is available in real-time at a resolution up to 2.5 minutes, ready to be distributed to the clients less than 60 seconds after nominal time. The PRECIP product results from a sequence of processing steps applied to the early-stage-processed radar data, aiming to produce the best quantitative precipitation estimation without using external measurements such as rain-gauge data in a short-time basis (e.g. hourly); the radar product incorporates only a broader, yearly-based, rain-gauge adjustment. The PRECIP product has a spatial resolution of 1 km (same as CombiPrecip) and is available for the period 2005-present.

RhiresD; RhiresM; RhiresY: Spatial analyses from rain gauge data have been elaborated as daily, monthly or yearly time resolution, precipitation fields over Switzerland.

Grid structures

Regular 1-km grid in the Swiss coordinate system over the domain covered by the C-band Swiss weather radar network.

Versions

Current version: CombiPrecip 3.1

Previous versions: CombiPrecip 2.1

Update cycle

The update cycle has not yet been decided.

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