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Documention of MeteoSwiss Grid-Data Products

Daily Precipitation (preliminary analysis): RprelimD

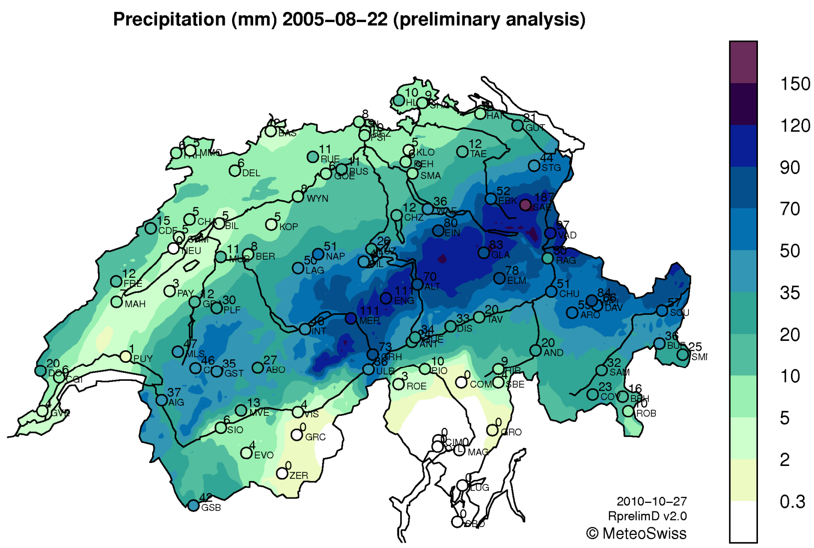

Figure 1: Preliminary analysis of daily precipitation (mm) for 22. August 2005. (Final analysis see Fig. 1 of product documentation for RhiresD.)

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

Application Real-time precipitation monitoring. Water resources and hydropower management. Hydrology, agriculture and tourism.

Overview RprelimD is a near real-time analysis of the distribution of daily precipitation in Switzerland. The analysis for a day becomes readily available on the following day. Its restriction to real-time measurements implies that RprelimD is a “preliminary analysis”, which is superseded by a more reliable “final analysis” from all (including manual) measurements after a delay of about one month (see RhiresD). RprelimD is addressed to qualitative or semi-quantitative applications in water resources and hydropower management.

Data base

RprelimD is based on measurements at stations with a near real-time data delivery into the MeteoSwiss central data archive. This involves approximately 95 mostly automatic stations from SwissMetNet (Konzelmann et al. 2007, MeteoSwiss 2010). The underlying station network (see Fig. 1) has an average inter-station distance of about 30 km and encompasses mostly flatland and valley floor stations, with high-mountain regions relatively under-represented.

The number of stations used for RprelimD is almost constant in time. The statistical approach of the analysis requires that only stations with a multi-year record can be integrated. Hence, measurements from newly installed automatic stations, such as those from ongoing extensions of the network by MeteoSwiss, can be integrated with some delay only.

The rain gauges of the automatic network of MeteoSwiss are tipping bucket gauges with an orifice of $200cm^2$ positioned 1.5 m above ground. Additional manual gauges with real-time data delivery are of the Hellmann type.

Method

The method of analysis used for RprelimD adopts a reconstruction technique, very different from conventional interpolation approaches. It builds upon a statistical relationship between high-resolution and coarse resolution data, which is calibrated from past data. To this end, the method of Reduced Space Optimal Interpolation (RSOI, Kaplan et al. 1997, see also Schmidli et al. 2001) has been adopted. It's application for RprelimD is described in detail in Schiemann et al. (2010).

In brief, RSOI for RprelimD encompasses: (1) the application of a Principal Component Analysis (PCA) to high-resolution precipitation analyses from product RhiresD; (2) the representation of precipitation variability by a restricted number of principal components; (3) the calibration of a linear relationship between the real-time station measurements and the retained PCA scores; (4) the application of this relationship to estimate a quasi high-resolution analysis for a day from the real-time measurements of that day.

The advantage of the reconstruction approach is that information is included not only from the actual real-time measurements but also – in a statistical manner – from past measurements of all stations (i.e. approx. 300 non real-time stations). This enhances the effective resolution compared to that achievable from the real-time measurements alone. In particular recurring mesoscale imprints of the topography are reproduced more realistically than with conventional interpolation.

Target users

RprelimD is addressed to users with a need for fast access times (quasi real-time) but prepared to accept compromises in accuracy. It is meant to provide an overview of recent rainfall activity in Switzerland for qualitative or rough quantitative management tasks in hydrology, hydropower and water resources management. Agronomy, insurance and tourism are other sectors of potential application.

Accuracy and interpretation

RprelimD is a fastly available, yet preliminary estimate of the distribution of precipitation in Switzerland. The way it is constructed, RprelimD attempts to approximate, from a limited station sample, the high-resolution analysis (RhiresD) that would be produced from a complete yet unavailable station sample. Therefore, even in the case of perfect reconstruction, RprelimD embodies the errors and uncertainties of the final analysis RhiresD (see the corresponding the product documentation). However, the limited number of measurements available for RprelimD imposes additional uncertainties:

The difficulties of automated rain-gauge measurement under windy and freezing conditions pose limitations to the accuracy of the measurements and constrain the placement of stations (maintenance). Moreover, gross errors may be discovered and corrected only with some delay. Therefore, the real-time analysis RprelimD is prone to more substantial measurement errors compared to RhiresD and the limited topographic representativity of the network involves additional risks for systematic error, especially at high altitudes.

The skill for reconstructing fine-scale precipitation variations from a coarser resolution network depends on the nature of these variations (see Schiemann et al. 2010): Recurring "climatic" features, such as the imprints of topography under similar flow situations, are resolved quite effectively by the reconstruction process. In contrast, patterns resulting from processes that are not geographically anchored, such as maxima from quasi-stationary cells or streaks from moving thunderstorms, are less well represented by RprelimD, and happen to be missing when not sampled by direct measurement. As a result, there is a remarkable case-by-case variation in how accurately RprelimD can reproduce RhiresD: Explained spatial variance fraction for daily totals (Nash-Sutcliffe Efficiency) varies between 0.25 and 0.98 with a median value of 0.83 in winter, and 0.76 in summer. Hence the reliability of RprelimD is clearly limited during summer days when precipitation systems are particularly small scale and of convective nature.

Fields of RprelimD generally have a smoother appearance than their high-resolution counterparts from RhiresD. Local extremes tend to be underestimated and rainfall areas tend to be smeared out into dry areas, even more so than in RhiresD. As a result, the effective resolution of RprelimD is considerably coarser, likely in the order of 30-50 km.

In summary, RprelimD provides an overview and rough estimate of precipitation activity in Switzerland. It is aimed primarily for qualitative monitoring applications or quantitative applications with a supra-regional focus (scales larger than about 50 km). Users should not expect local extremes (dry or wet) to be accurately reproduced. Quantitative applications will have to tolerate errors of several ten percent even for area means estimates of several 100 km^2.

Related products

RhiresD: The final analysis of daily precipitation with all station measurements included, noteably the manual measurements not available in real time. Compared to RprelimD, RhiresD is qualitatively more accurate, has a higher effective resolution but is accessible only with a delay of about one month.

Grid structures

RprelimD is available in the following grid structure:

ch02.lonlat, ch01r.swisscors

Versions

Actual version: RprelimD v2.0

Previous versions:

RprelimD v1.0: Based on interpolation as described in RhiresD, but using real-time measurements only. (This version was not distributed outside MeteoSwiss).

Update cycle

RprelimD is updated every day. The analysis for day DD is available at 10:00 of day DD+1.

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Documention of MeteoSwiss Grid-Data Products

Daily Precipitation (final analysis): RhiresD

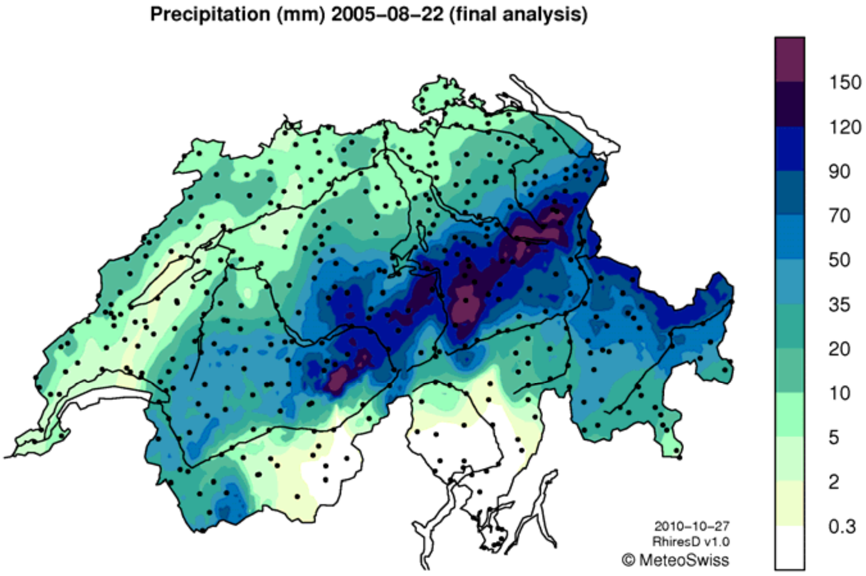

Figure 1: Daily precipitation total (mm) for 22. August 2005. Analysis derived from automatic and manual measurements.

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

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

Overview RhiresD is a spatial analysis of daily precipitation covering the entire territory of Switzerland and extending over a multi-decadal period (1961-present). It provides detailed spatial information and high accuracy by exploiting all available (i.e. automatic and manual non-realtime) measurements (typically 420 each day). Apart from basic monitoring, RhiresD serves a broad range of planning tasks where quantitative process models with precipitation input are used. It is typically available with a delay of 3-6 weeks.

Data base

RhiresD is based on daily precipitation totals measured at the high-resolution rain-gauge network of MeteoSwiss. It uses all quality checked station measurements available for a particular day to ensure maximum effective resolution and accuracy. Therefore, the station base varies slightly from day to day. Over the long term, the number of stations increased from 420 in the early 1960ies to about 520 in the mid 1970ies and gradually decreased thereafter, reaching 430 after 2005.

The geographical distribution of rain-gauge stations in Switzerland is reasonably balanced in the horizontal (see e.g. Fig. 1), but 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).

The majority of the rain gauges operated since 1961 are/were manual Hellmann type gauges with an orifice of 200cm^2 positioned 1.5 m above ground. Since the early 1980ies approximately 70 stations are equipped with automatic tipping bucket gauges.

Method

The precipitation analysis for day DD is obtained in several steps: (1) Spatial interpolation of the climatological mean precipitation measurements for the calendar month of day DD (reference period 1971-1990); (2) Calculation of relative anomalies of station measurements on DD with respect to the climatological mean in 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. To this end a version of the PRISM algorithm by Daly et al. (1994, 2002) was 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).

The interpolation in step (3) adopts a weighting scheme, which emphasizes the contribution of measurements which are close to the analysis point and/or which 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. Details of the interpolation scheme are described in section 4.1 of Frei et al. (2006) and in Frei and Schär (1998).

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 contributed to the analysis and physical understanding of recent flooding events (Bezzola and Hegg 2007, 2008; Bezzola and Ruf 2009). Applications in climatology and meteorology include the analysis of precipitation variability and trends, the evaluation of weather forecasting and climate models, and climate change downscaling.

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 un-gauged 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). There is a general tendency (i.e. a systematic error) to overestimate light and underestimate intense precipitation. If gridpoint values are interpreted as area mean values (e.g. over one or several 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. A model-based analysis for the heavy precipitation days in August 2005 revealed errors in the order of 5-30% if gridpoint estimates were interpreted as 15x15 km^2 area mean values (Frei et al. 2008). These numbers are however sensitive to the nature of the precipitation. Larger errors are to be expected for days with localized thunderstorms.

Grid spacing vs. effective resolution: The substantial interpolation errors for point estimates pinpoints to the limited effective resolution of RhiresD (in fact of any gridding from station data only). The km-scale gridpoint spacing does not imply that these scales are resolved. The effective resolution of RhiresD is in the order of 15-20 km or larger (typical inter-station distance). The user should be very careful in relying on estimates at single or very few gridpoints. In particular, RhiresD is not suitable to obtain 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 high climatological homogeneity with daily resolution can contact MeteoSwiss to investigate options for a dedicated homogenous regional data product.

Related products

RprelimD: A preliminary estimate of the distribution of daily precipitation based on a much smaller sample of stations but available in quasi real time (with a delay of one day). RprelimD is addressed to users with management tasks needing real-time data access. RhiresD is clearly more accurate.

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

Grid structures

RhiresD is available in the following grid structures:

ch02.lonlat, ch01r.swisscors, ch.cosmo2.rotpol, ch.cosmo6.rotpol

Monthly Precipitation: RhiresD

Versions

Actual version: RhiresD v1.0

Previous versions: none

Update cycle

RhiresD is updated once every month to include the daily fields from the previous calendar month. The update is available typically on the 25th .

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Documention of MeteoSwiss Grid-Data Products

Monthly and Yearly Precipitation: RhiresM and RhiresY

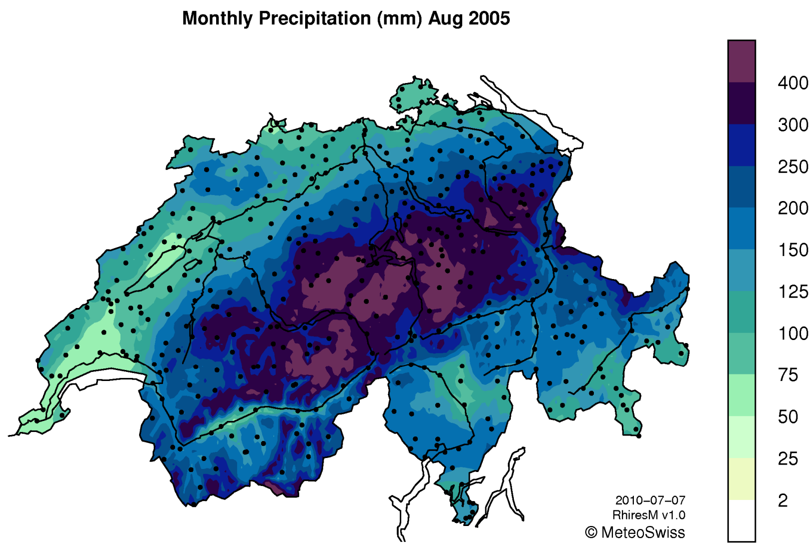

Figure 1: Monthly precipitation total (mm) and incorporated station measurements for August 2005

Variable Precipitation accumulated over the calendar months (the year), including rainfall and snowfall water equivalent. In millimeters (equivalent to liters per square meter).

Application Climate monitoring, ecology and agriculture, water resources, glaciology, hydropower, tourism.

Overview RhiresM and RhiresY are spatial analyses of monthly and yearly precipitation respectively, covering the entire territory of Switzerland and providing detailed spatial information. It exploits all available station measurements of the MeteoSwiss operational network (more than 420 each month), and covers a multi-decadal period (1961-present). The two products addresses requirements of agronomists, ecologists and glaciologists running environmental process models. Moreover, it delivers a basis for planning and management tasks on water resources, hydropower and tourism.

Data base

RhiresM/RhiresY are based on monthly/yearly precipitation totals measured at the high-resolution rain-gauge network of MeteoSwiss. It uses all station measurements available for a particular month to ensure maximum possible effective resolution. Therefore, the station base varies over time (from month to month). The number of stations increases from 420 in the early 1960ies to about 520 in the mid 1970ies and gradually decreases thereafter, reaching 430 after 2005. 270 rain gauges (about 50% of the stations) come with an uninterrupted record since 1961.

The geographical distribution of rain-gauge stations in Switzerland is reasonably balanced in the horizontal (see e.g. Fig. 1), but 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).

The majority of the rain gauges operated since 1961 are/were manual Hellmann type gauges with an orifice of $200cm^2$ positioned 1.5 m above ground. Since the early 1980ies approximately 70 stations are equipped with automatic tipping bucket gauges.

Method

A field of precipitation in month MM is obtained through the following procedure: (1) Spatial interpolation of the climatological mean precipitation measurements for the calendar month of MM (reference period 1971-1990); (2) Calculation of relative anomalies of measured precipitation in MM with respect to the climatological mean in 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. To this end a version of the PRISM algorithm by Daly et al. (1994, 2002) was 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 monthly precipitation is to reduce the risk of systematic errors due to the under-representation of measurement stations at high elevations (Widmann and Bretherton 2000).

The interpolation in step (3) adopts a weighting scheme, which emphasizes the contribution of measurements which are close to the analysis point and/or which 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. Details of the interpolation scheme are described in section 4.1 of Frei et al. (2006) and in Frei and Schär (1998).

Target users

Thanks to its multi-decadal extent (49 years currently) and high effective resolution, RhiresM/RhiresY address the needs of a wide range of applications. In climatology, it is the primary data product for regional climate monitoring, research on climate variability and climate change downscaling. Moreover, it is suitable as input into environmental process models in a variety of fields such as agriculture, ecology, hydrology and glaciology. Also, it provides an interesting data base for social and economic planning and management, such as for water resources, hydropower and tourism.

Accuracy and interpretation

The accuracy of RhiresM/RhiresY depends on the accuracy of the underlying rain-gauge measurements and the capability of the interpolation scheme to reproduce precipitation at un-gauged 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. RhiresM must therefore be expected to generally underestimate precipitation particularly in months and at locations with snowfall.

Interpolation errors: A “leave one out” cross-validation reveals a relative standard error of +/– 20% in point estimates for Jura and the Swiss Plateau and of +/– 25-30% for the Alps and the Alpine south side. Seasonal variation of errors is small. Particularly large relative errors occur during dry months and in inner Alpine valleys (e.g. the Valais) as well as at high elevations in the Alps. The average fraction of explained spatial variance is 75% (Nash-Sutcliffe Efficiency, Nash and Sutcliffe 1970). It is to be noted that estimates of area mean values (obtained by averaging gridpoint values) are much more accurate with error statistics decreasing quickly with the size of the area (see also Frei et al. 2008).

Temporal homogeneity: Temporal variations in the station network invoke climatological inhomogeneities in RhiresM. These are expected primarily on a local to regional scale, while they tend to average out for larger scale averages. Users requiring climatological homogeneity are referred to product RanomM, however this is associated with a compromise in the effective spatial resolution.

Grid spacing vs. effective resolution: The km-scale spacing of gridpoints does not imply that these short scales are fully resolved in RhiresM. The short scale patterns (e.g. those evident in Fig. 1) are reflecting the climatological topography-precipitation relationships. The effective resolution of RhiresM is in the order of 15-20 km, corresponding to the average inter-station distance. Frei et al. (2008) give a thorough discussion of short-scale uncertainties in gridded precipitation products.

Related products

RhiresM and RhiresY are related: While the same analysis procedure is used for both products, RhiresM takes monthly but RhiresY yearly precipitation measurements from stations. As a result, there is no strict consistency between the two products, i.e. adding the months of a year from RhiresM does not reproduce RhiresY exactly. This is due to differences in the underlying measurement data, when stations only cover part of the year. Differences are however insignificant in practice.

RhiresD: Similar to RhiresM but for the daily precipitation sum. Again, there is no strict consistency between the two products, i.e. adding the days of a month from RhiresD does not reproduce RhiresM/RhiresY exactly. Differences are however insignificant in practice.

RanomM: Deviation from the climatological mean precipitation (reference norm period 1961-1990). This product is based on the sub-sample of stations for which there exist approved norm values. Hence RanomM is of slightly inferior effective spatial resolution. RanomM is recommended for applications where long-term homogeneity is a key requirement and absolute values are not needed.

Grid structures

RhiresM and RhiresY are available in the following grid structures:

ch02.lonlat, ch01r.swisscors, ch.cosmo2.rotpol, ch.cosmo6.rotpol,

Versions

Actual versions: RhiresM v1.0, RhiresY v1.0

Previous versions: none

Update cycle

RhiresM is updated every month, RhiresY every year. The analysis for month MM is available after day 25 of month MM+1. The analysis for year YY is available in January of year YY+1.

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