# CALCULATION OF GRIDDED PRECIPITATION DATA FOR THE GLOBAL LAND-SURFACE USING IN-SITU GAUGE OBSERVATIONS

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## ABSTRACT

The Global Precipitation Climatology Centre (GPCC) provides the international research community with monthly precipitation analyses based on in-situ observed data from rain gauge networks. In particular, the Centre delivers the in-situ basis (its so called „Monitoring Product") for the satellite-gauge combinations of GPCP and NCEP, but in general, it contributes to analysis, monitoring and research activities related to climate and water. The technical functions comprise data collection, quality control, spatial analysis, and error quantification. With respect to different user requirements concerning accuracy, spatial resolution and timeliness, the GPCC delivers various gridded products optimised either for timeliness, accuracy or homogeneity: The „First Guess" of the precipitation anomaly and the "Monitoring Product" are created month by month on a regular basis, the first one within five days the other within two months after observation. Two more products are data re-analyses, the "Full Data Product" optimised for best individual accuracy (by use of all available data), and the "Long-Term Climatology" based upon homogeneity-controlled data time-series from selected stations. The gridded products are generated by an operational analysis system with components for (1) integration of data from different sources, (2) quality-control, and (3) calculation of area-averaged precipitation on the gridcells. Errors are caused by deficiencies of the measuring method and by a regionally insufficient network density. Therefore, accuracy of the gridded results largely varies depending on the individual temporal and spatial conditions. The total analysis error resulting from the measuring errors and sampling error rates can be estimated.

## 1. INTRODUCTION

Precipitation data, measured by conventional (rain) gauge networks, are still an important and generally requested information to obtain area-averaged precipitation for the land-surface. With regard to quantification of precipitation amounts reaching the surface, satellite-based estimates are subject to larger biases and stochastic errors; in-situ observations are needed for adjustment, validation, verification (Barrett et al. 1994, Rudolf et al. 1996, Rubel and Rudolf 2001). But also gauge-observed data and interpolated gridded data fields don't represent the full truth: Errors result first from systematic measuring errors (undercatch by evaporation losses and drift of drops or snow particles by the wind) and second from incomplete observations (spatial coverage, temporal gaps). In addition, the experience shows, that individual errors emerge during the further data transmission and processing, e.g. by typing, coding and decoding, or reformatting of the data. Therefore, quality-control for the data and products, error assessment and bias-correction is very necessary.

The Global Precipitation Climatology Centre (GPCC) has been established in 1989 on invitation of the World Meteorological Organization (WMO). It is operated by Deutscher Wetterdienst (DWD, National Meteorological Service of Germany) as a German contribution to the World Climate Research Programme (WCRP). From the beginning, the Centre is a component of the WCRP Global Precipitation Climatology Project (GPCP). Later (1994), long-term operation of the GPCC has been requested by WMO with regard to the Global Climate Observing System (GCOS). This has been accepted by DWD. So far, 176 countries have delivered data to the GPCC, on request of WMO, and in order to provide a sufficient basis for the analysis of spatial precipitation structures. The products of the GPCC, gauge-based gridded precipitation data sets for the global land surface, are world-wide used by many researchers at various institutions, e.g. within water-related projects of WMO, FAO, UNESCO and UNEP.

All primary products of the GPCC are completely based on numerically interpolated gauge observations (i.e. without use of any satellite or model data) and represent area-mean monthly precipitation on gridcells. The results do not describe precipitation at point-size locations or individual stations. The grid size has been defined to 2.5° latitude by 2.5° longitude by the GPCP Implementation and Management Plan (WMO 1990). The reason for this coarse resolution is first that geostationary satellite infrared data are only stored in the format brightness temperature histograms 2.5° gridcells for the whole project period. A second reason is the limited availability of in-situ observations near real-time and on global scale. Even with 7,000 gauges, the mean data coverage for the global land surface is about 2 gauges per 2.5° gridcell. At least 5 gauges should be reporting within a gridcell in order to obtain a monthly area mean precipitation being suitable for adjustment of satellite-based data fields. However, all GPCC gauge products are available for three resolutions: 0.5°, 1.0° and 2.5°. Besides the monthly precipitation fields also error-related information as data density (number of stations on the grid) and climatological bias correction factors are provided by the GPCC. So users are able to consider the regional accuracy of the respective precipitation results.

The following sections present the gauge data basis of the GPCC analysis products and the major data processing and analysis components. Finally the features of the different products are presented and complemented by hints and recommendations for our users.

## 2. THE GAUGE DATA BASE

Although more than 200,000 precipitation gauges are world-wide operated in national meteorological or hydrological observation networks, only a subset of about 7,000 stations is internationally exchanged between the National Meteorological Services (NMSs) on a regular basis. These data are disseminated near real-time by the NMSs into the (World Weather Watch) Global Telecommunication System (GTS). All other data are primarily used for the needs within the individual countries and exchanged under the particular national rules. By the mean-time, some few NMSs provide their national data for free access on the Web.

The aim of the GPCC is to fulfil the accuracy goal as far as possible, at least to obtain a sufficient data coverage over major parts of all continents, by compilation of gauge data from all available sources, in particular from:

**1.** Meteorological synoptic data (SYNOP) accessible at DWD via GTS (Offenbach, Germany)
**2.** Monthly climate bulletins (CLIMAT) accessible at DWD via GTS (Offenbach, Germany)
**3.** Monthly precipitation derived from SYNOP data by NOAA/CPC (Washington DC, USA)
**4.** National data contributions by WMO Members (176 countries so far)
**5.** Data collections of some international regional projects (e.g. BALTEX, SE Asia)
**6.** Global data collection of the Climate Research Unit (CRU, Norwich, UK)
**7.** Global data collection of the UN Food and Agricultural Organisation (FAO, Rome, Italy)
**8.** Collection of the Global Historical Climatology Network (GHCN, NCDC Asheville, USA)

Data sources No. 1, 2 and 3 enter the GPCC within one month after observation, and can be used for the early analyses. A much longer time is required to obtain and integrate the „additional data“ from the sources No. 4 to 8. Merging of the data will lead to the best possible data base. If data are available from different sources for the same stations and time, a comparison is very useful for quality-control and assessment of the accuracy

Due to different formats and other features, the data from the distinct sources need to be pre-processed at GPCC in different ways. In the following, the processing is described separately for the different data sources:

## 2.1 Meteorological synoptic data (SYNOP) received at DWD, Offenbach

About 8,000 meteorological stations are listed in the WMO Volume A to disseminate via the GTS for global exchange immediately after observation. The primary purpose of the data is the analysis of global current weather charts and initialisation of numerical weather prediction models. SYNOP bulletins comprise a large set of meteorological variables in a special international code. The GPCC evaluates the precipitation-related components:

- The precipitation group: $t_R$RRR with
  $t_R$ = time interval ($t_R$ can be 1 hour, 3, 6, 12, 18 or 24 hours)
  RRR= precipitation total for the interval $t_R$ in mm, respectively in tenths of mm for precipitation amounts less than 1 mm (RRR $\geq$ 990)
- The weather group ww$W_1W_2$
  ww and $W_1$,$W_2$ describe the observed current weather (e.g. ww = 65: heavy rainfall) and the past weather.

In order to obtain the maximum of usable data from SYNOP, the GPCC data processing routine includes some automatic quality checks and corrections:

- Correction of obvious coding errors
- Consistency check of RRR for messages overlapping in time
- Plausibility check of RRR with respect to typical maximum values
- Consistency check of RRR versus ww and $W_1$,$W_2$
- Completion of the SYNOP by $t_R$000 in the case that the weather groups indicate no precipitation for a certain interval $t_R$ and precipitation groups are missing.

For months being completely covered by SYNOP precipitation data monthly totals can be easily calculated. This is the case for, on average, only 2000 of 8000 SYNOP stations. The other 6,000 stations have an incomplete monthly coverage. smaller or larger data gaps. After statistical intercomparison studies (Schneider et al. 1992) incomplete time-series are accepted for a coverage of at least Pct = 70% (about 21 days of a month, in order to obtain a maximum number of reasonable monthly data. The monthly precipitation total $P_M$ is calculated by

$$P_M = R_{Sum} * 100 / Pct \qquad (1)$$

with $R_{Sum}$ = sum for the observed precipitation intervals, and if Pct >= 70%

For a monthly coverage of 70% the mean difference between the monthly totals calculated as under (1) and reference data (CLIMAT, see 2.2) is about 15% of the reference, and increasing with decreasing coverage. The SYNOP-based monthly totals are accompanied by quality indices representing the temporal coverage and corrections of individual SYNOPs.

### 2.2 Monthly climate bulletins (CLIMAT) received at DWD, Offenbach

In the framework of the regulated global data exchange, monthly climatic data by CLIMAT bulletins being disseminated by the countries via GTS for some 2000 stations. The CLIMAT bulletins include monthly means or totals for a number of variables. These data are compiled from reprocessed daily or synoptic observations by the originator and released. The data are assessed to be of high quality because some control of quality and completeness was performed. In spite of this, some errors still occur partly caused by the manual coding process. Therefore, the received coded data are first checked by DWD with regard to typical coding errors and to completeness and consistency. The plausibility of monthly precipitation is examined using additional information being also part of the CLIMAT bulletin, e.g. number of days with precipitation more than 1 mm and the quintile of the monthly data with regard to the frequency distribution. By this, questionable data are recognized and flagged. Quality-controlled CLIMAT precipitation has an important reference function, expressed by a high quality allocated to the data by the GPCC.

### 2.3 Monthly precipitation derived from SYNOP data at the CPC of NCEP, Washington DC

As a third source, the GPCC takes monthly precipitation data from by the Climate Prediction Center (CPC) which are mainly based on SYNOP data. The global collective of SYNOP data received at Washington DC from the GTS is not fully overlapping the collective received at Offenbach. While the NCEP receives more data for the Americas, Eastern Russia and some African regions, the DWD reaches a much higher data density over Europe. The CPC procedure to estimate monthly precipitation totals and especially to fill gaps in the SYNOP precipitation series is different from the DWD method described under section 2.1. The CPC includes precipitation data being statistically estimated from the qualitative weather observations ww and $W_1$,$W_2$ (see section 2.1). However, the temporal fraction based on really measured data is not clearly indicated with the monthly precipitation totals. The GPCC allocates estimated quality indices.

In order to obtain the best possible spatial data coverage at the earliest time as required by the GPCP and other users, the GPCC merges for its Monitoring Product the monthly totals from three data sources CLIMAT, DWD-SYNOP and CPC (Figure 1).

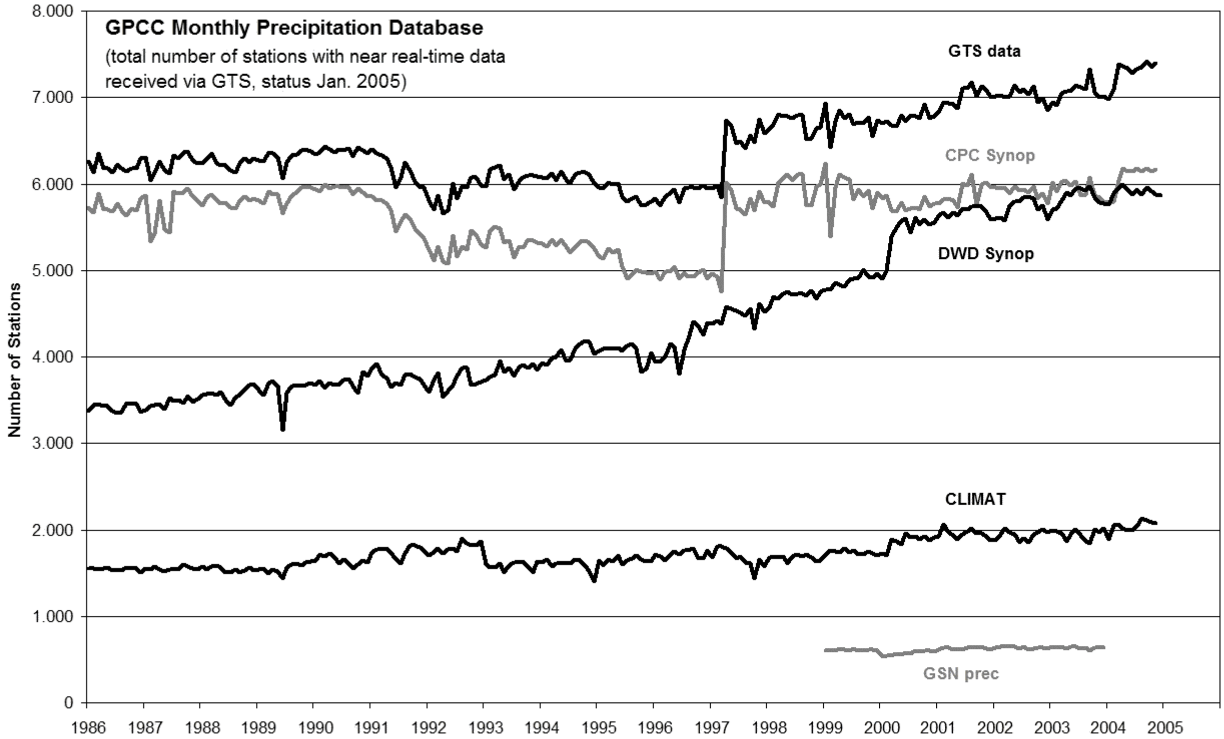


**Figure 1.** Temporal coverage by monthly precipitation data being timely available via GTS (totally) from the primary sources CLIMAT and SYNOP (status January 2005).

## 2.4 Additional monthly precipitation data from dense national gauge networks

More data, as required for quantitatively reliable precipitation analyses, are available from the individual countries on request, however, not within a few months after observation. The time required for data processing at the individual countries differs, and is for most countries more than one year. But gridded analysis results of high accuracy are still very requested, especially for global climate variability and hydrological studies, even if the delay is some years.

The GPCC actively acquires additional data by bilateral correspondence with the responsible national agencies. All WMO Members are informed by circular letters of WMO about the international task of the GPCC and the corresponding data requirements. The GPCC has no funds for data purchasing and even not for covering any shipping costs. The data delivered are contributions of the countries to the international task of the GPCC and are restricted to the defined purpose.

The data are delivered to the GPCC mostly after individual request. The volume and timeliness of the packages largely differ, with the time delay resulting in a gradual temporal decrease of the number of stations being available for the analyses starting in the year 1986 (Fig. 2). The year with the best data coverage is 1987 with monthly precipitation data being available for about 43,000 stations.

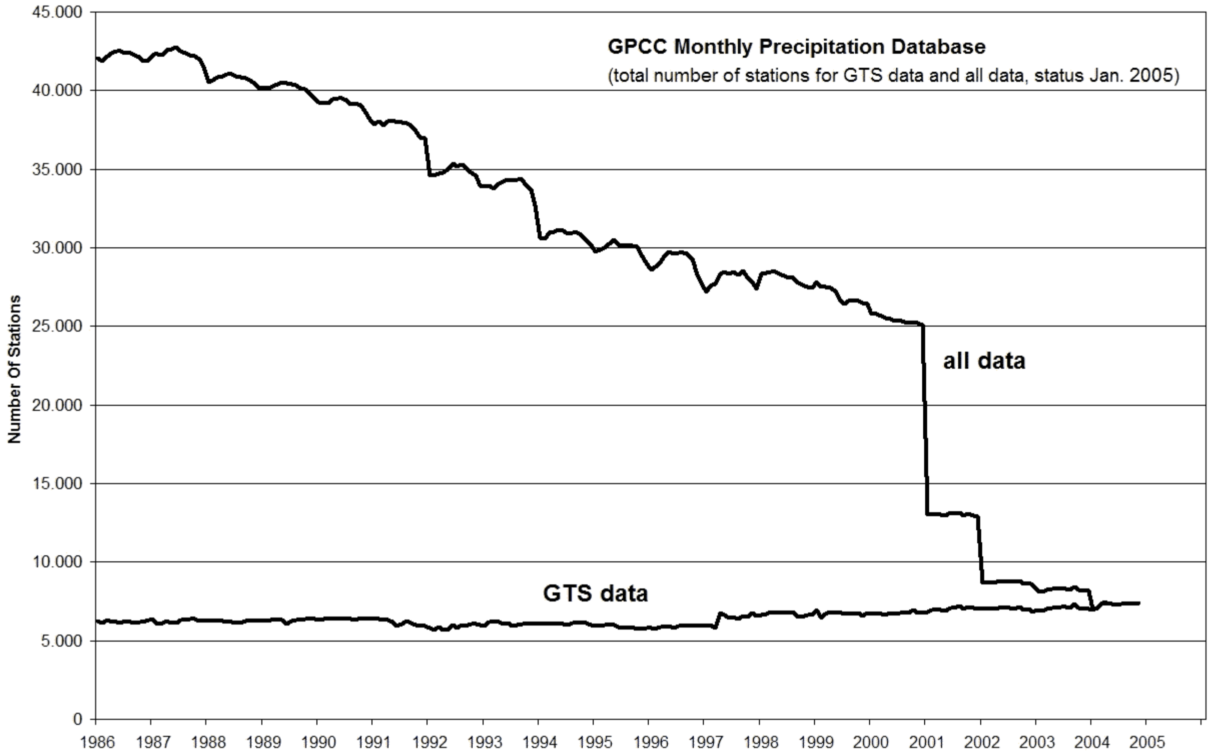


**Figure 2.** Temporal coverage by monthly precipitation data from all sources and those being timely available from GTS (status January 2005).

The processing of the individual data collectives requires a number of steps:

a) Identification of the file content (variables, period), general structure and specific format
b) Reformatting the file into a unique GPCC format
c) Visualisation of the reformatted file in maps and diagrams for a quick overall quality check
d) Clear identification of the stations and meta data control by a semi-automatic comparison of the delivered meta data and the existing GPCC stations master catalogue
e) Loading of the data into Relational Data Base Management System (RDBMS)
f) Semi-automatic quality-control of the monthly precipitation data based on a comparison of the data from the different sources with respect to the spatial and statistical data structure.

All precipitation data received are stored in the data bank separately for the data sources (CLIMAT, DWD-SYNOP, CPC, National, Regional Projects, CRU, FAO and GHCN) and together with meta information and quality indices assigned to the data. The comparison of the data from the different sources is a valuable basis for the quality control and assessment of the data to be selected for analysis.

All products are generated out of this data base by selection of data with respect to the data quality and product specifications. The spatial distribution of 7,000 stations for the GTS data basis and of all 43,000 stations for the best covered month (July 1987) is shown in Fig. 3. One can recognize that there still occur large data-sparse regions, in particular over parts of Africa, Central and South America, East and Central Asia.

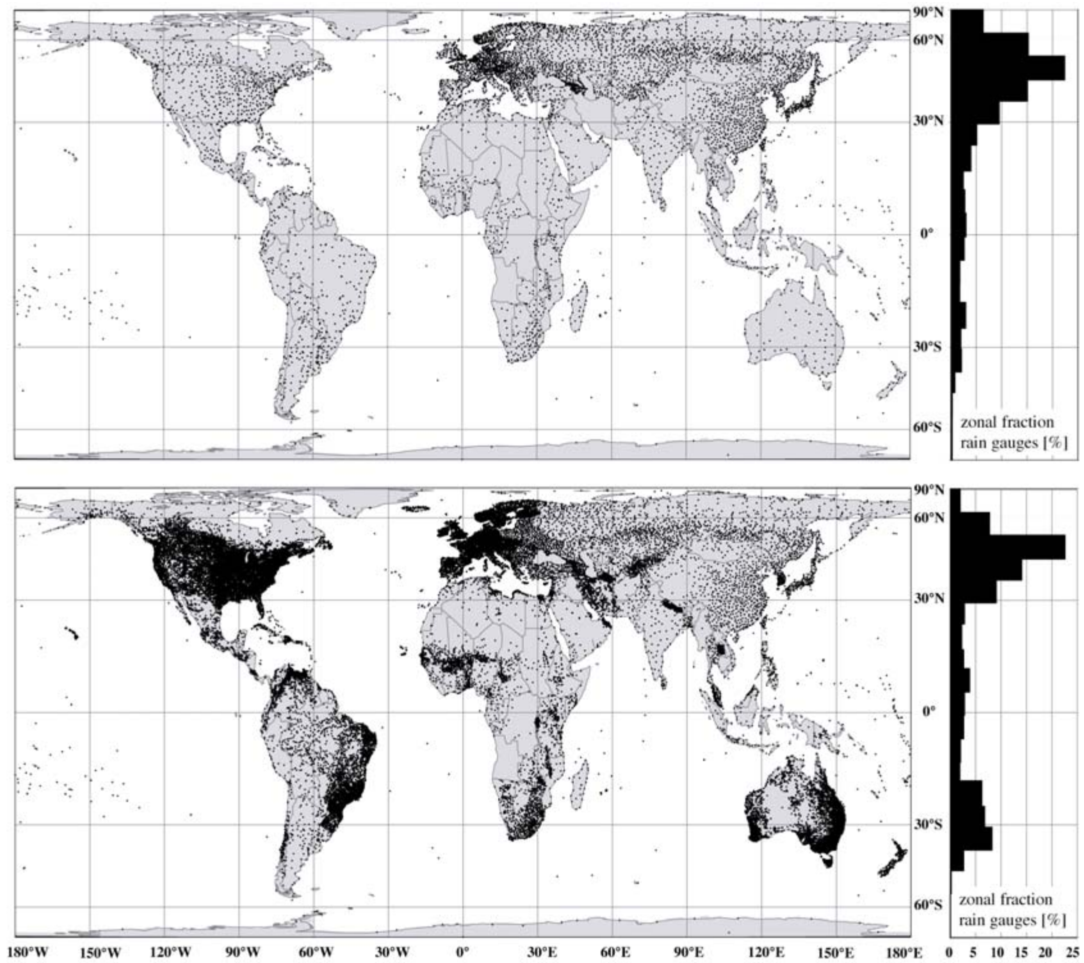


**Figure 3.** Locations of the GTS stations (top) and of all stations with precipitation data from at least one of the sources for July 1987 (status 2003, bottom). From Rudolf and Rubel, 2005).

## 3. THE SEMI-AUTOMATIC GPCC QUALITY-CONTROL SYSTEM

The necessity of an effective quality-control is evidenced by any experience in processing of observational meteorological data. Data are partly affected by typing or coding errors and other modifications occurring on the way from the originator to the archive. Such errors can have a relevant influence on the analysis results.

Conditions complicating quality-control of precipitation data are:

- The temporal and spatial variability of precipitation is very large.
- A large number of the statistical outliers are true extreme data.
- Meta-information to be used as objective quality criteria is mostly not available.
- In many cases it is not possible to get timely replies from the data originator.

Because of the high variability of precipitation (monthly totals occur in the range from 0 to more than 1000 mm) a fully automatic quality-control would eliminate all data being classified as outliers including those which are real extremes. These true data, however, are very important to describe the variability of precipitation by the gridded analysis. This problem can only be solved by the performance of a visual check of questionable data. The GPCC has optimized the QC procedure by a system of successive automatic and visual checks with respect to the features of the different data sources and the specific meta information being available for those. The automatic part of the control-procedure has not been designed to correct data, but to identify and flag questionable data and thereby reduce the number of data for which a visual control is necessary.

### 3.1 Identification of the stations and meta data control

In order to avoid a spatial misallocation of climatic data in the analysis, all data sets supplied to the GPCC are controlled with regard to the clear identification and the correct location of the observing stations. This task is supported by data visualization software which recognizes the plausibility of the geographical distribution of the stations within the country boundaries and the general structure of precipitation time-series within the climatic context. Data and meta data received from different sources are cross-checked. In case of unclear meta data, the supplier is contacted, if possible. If there is no reply, the station co-ordinates are obtained from other data sources (comparison to meta data delivered with other data sets) and from other sources of geographical information. After identification of the stations the meta data are harmonized and stored in the GPCC master catalogue.

### 3.2 Quality-control of the monthly precipitation data

In order to avoid loading mismatched or overall erroneous data sets into the data bank, all precipitation data sets have already been precontrolled separately using different techniques fitting the respective data sources, as described in the sections 2.1 to 2.4. However, the precontrol is not able to recognize or eliminate most of the individual data errors. This requires a synopsis of the data from all sources. The semi-automatic QC system of the GPCC combines the quality control with the spatial analysis with the following steps

- automatic QC and data selection
- first spatial analysis using the selected data
- computer-assisted manual/visual revision
- final spatial analysis using the revised data.

*The automatic component:*
In the automatic part, all precipitation data of the month to be analysed, are checked first against climatological mean data and frequency distribution of the time-series at the considered station, and second for consistency with the spatial average resulting from the first analysis of the data at the given station and at the neighbouring stations. In addition to that the data from the different sources are checked against each other. According to a suitable combination of these different criteria for spatial or statistical outliers, only a small portion of the data (less than 10%) is classified as questionable and flagged by the automatic system. Based on the comparisons, all data from all sources are complemented by quality flags, and the expected best value at a station is pre-selected to be used for a first preliminary spatial analysis (interpolation and gridding).

*The visual/manual component:*
After the first analysis, all stations are plotted in a world map, displayed by a graphics work-station. At each station in the map, the data source being pre-selected is identified by a symbol, and stations with questionable data are marked by colour. These data can be visually reviewed by a trained expert. The data controller can zoom in the map and view all relevant information being available for the observing station considered, including the precipitation data of the neighbouring stations and background fields such as the preliminary analysis result, gridded

climatologies, a 3dimensional display of the orography, or information of extremes (e.g. floods) reported for the region. Data automatically marked as questionable can be confirmed to be true after the visual check or manually corrected. Many decisions require some individual investigation before. The controller has the following options to

- confirm the marked data to be true
- change the data source selection for the individual station, if a more reliable precipitation amount from another source is available
- modify the quality index of the selected data
- correct data if an obvious error is recognized (e.g. factor ten error)
- correct the station meta data if the station co-ordinates are recognized to be wrong
- flag the data of a station not to be used in the final spatial analysis (“trash”).

All original as well as corrected data are archived in the RDBMS of DWD. Figure 4 illustrates the data flow in the main processing steps.

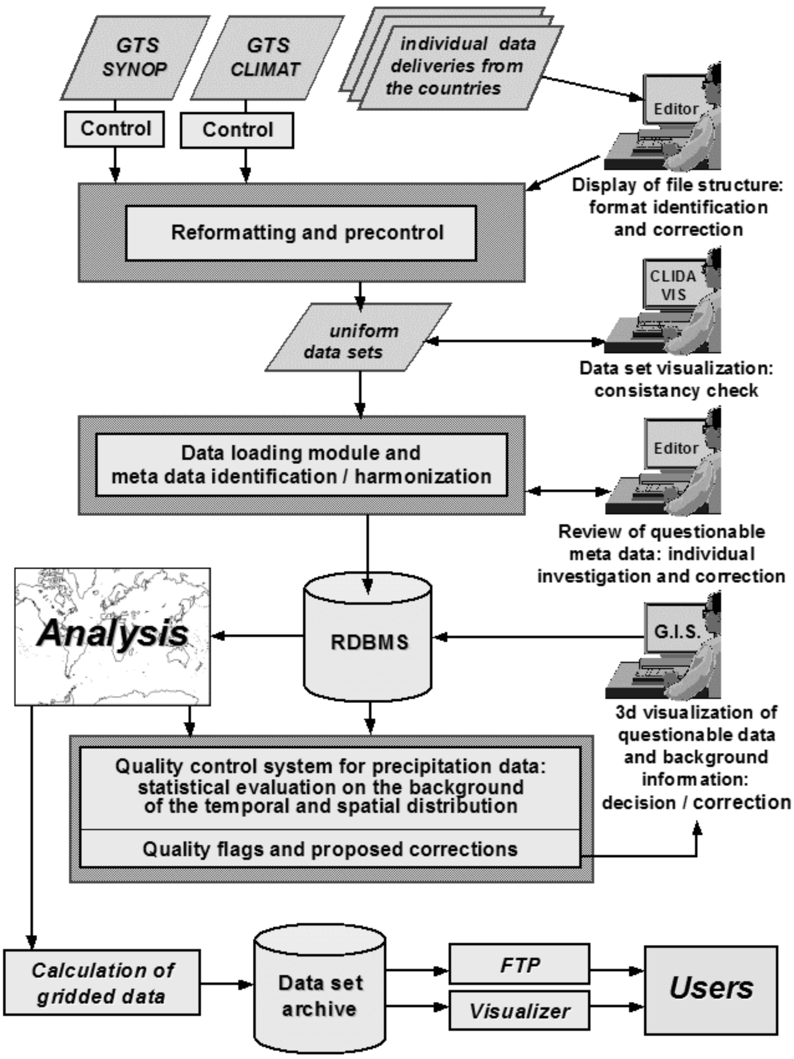


**Figure 4.** Simplified scheme of processing, quality-control, archiving, analysis, and distribution of precipitation data at the GPCC

## 4. CALCULATION OF GRIDDED PRECIPITATION DATA SETS

The calculation of area means on the gridcells from gauge observations consists of three major steps, the interpolation from stations to regular gridpoints (0.5° geogr. latitude/longitude), the calculation of area-mean precipitation for gridcells (0.5° geogr. latitude/longitude), and the assessment of area-mean precipitation for larger gridcells or other areas (e.g. river basins).

### 4.1 Interpolation of the irregularly distributed gauge data onto regular gridpoints

The empirical interpolation method SPHEREMAP (Willmott et al., 1985) is routinely used at the GPCC since 1991 for the calculation of grid point results of 0.5° lat./long.
SPHEREMAP is a spherical adaptation of Shepard's empirical weighting scheme (Shepard, 1968) which is taking into account

(a) the distances of the stations to the gridpoint (for limited number of nearest stations),
(b) the directional distribution of stations versus the gridpoint (in order to avoid an overweight of clustered stations), and
(c) the gradients of the data field in the gridpoint environment.

SPHEREMAP was selected, adapted and implemented at GPCC in 1991 for operational objective analysis of global precipitation, following external studies (Legates, 1987; Bussieres and Hogg, 1989) and internal intercomparison results (Rudolf et al., 1992, 1994). These studies indicated the SPHEREMAP method being particularly suitable in analysis of global precipitation climatologies. In an intercomparison study of 4 different interpolation schemes (Bussieres and Hogg, 1989) it was the best of the empirical schemes and did a job almost as well as Optimum Interpolation.

### 4.2 Calculation of area-mean precipitation for basic gridcells (0.5° lat./long.)

A first area-average precipitation is calculated as arithmetic mean from the interpolated data from (up to) 4 gridpoints representing the corners of a 0.5° by 0.5° gridcell. For this, only those of the corners are used which are located over land, so the mean represents the land-surface precipitation. The 0.5° gridcell means only represent the land-surface proportion of the total gridcell area. which has been calculated for 0.5° gridcells by the GPCC using the USGS GTOPO-30 data.

### 4.3 Calculation of area-mean precipitation for larger regions using the 0.5° gridcell means

Area-average precipitation has been calculated by the GPCC on coarser grids (1.0° or 2.5°) from the 0.5° gridcell means, as it is possible to calculate average precipitation for river basins, continents or otherwise defined regions using the 1.0° and 0.5° lat./long. gridded data sets published by the GPCC. However, it is very important, to take into account not only the poleward convergence of the meridians but also the relative land-surface proportion of the gridcells used.

$$PAM = \text{Sum}\ (\ PGM\ (i,j) * \cos(\varphi)\ (j) * LP(i,j)\ )\ /\ \text{Sum}\ (\ \cos(\varphi)\ (j) * LP(i,j)\ ) \qquad (2)$$

with PAM : Precipitation area mean
PGM : Precipitation gridcell mean
LP : relative land-surface proportion
$\varphi$ : geogr. latitude
i,j : gridcell counter: i west-east, j south-north

The land-surface proportion is not used for the calculation of accumulated regional means, the results will be quite different if 0.5° or 1.0° and 2.5° results are used and the considered area is cut by a coastline. Figure 5 illustrates the geometry of the GPCC procedure.

The land-surface proportion for 0.5°, 1.0° and 2.5° lat./long. gridcells is available from the GPCC in order to provide the GPCC users with the information required.

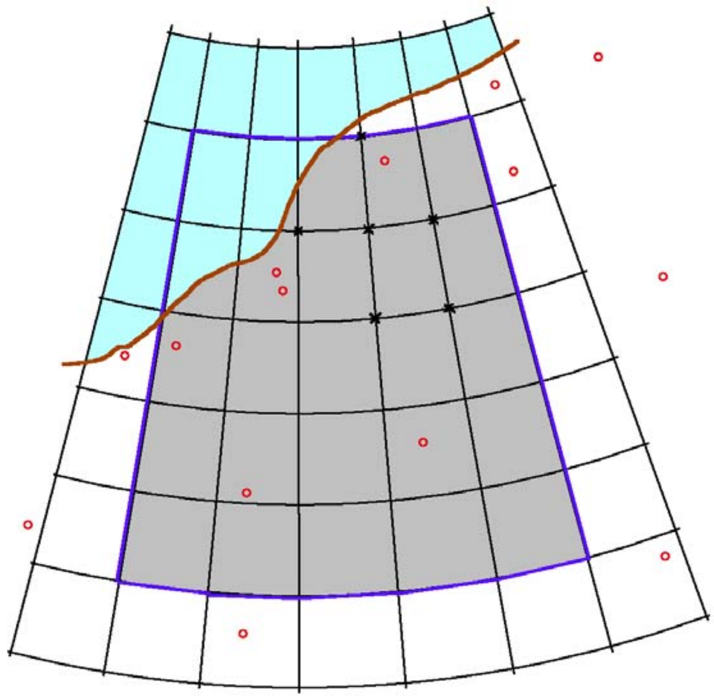

**Figure 5.** The grid geometry of GPCC's analysis products showing: station locations (circles), 0.5° gridpoints (crosses), 0.5° gridcells (inner boxes) one 2.5° gridcell including 25 basic gridcells, the coastline, and southeast of it the part of the area represented by the gauge observations.

## 5 ERROR DISCUSSION

The two most critical errors are, first, the systematic gauge measuring error which generally leads to an undercatch, particularly for solid precipitation and high wind speeds (Goodison et al, 1998) and second, the sampling error, which depends on the density of the gauge locations and the variability of the precipitation field according to the climatic/orographic conditions (WMO, 1985).

### 5.1 Systematic gauge measuring error

Observations gained under research conditions showed that the error is caused by wind drift, evaporation and wetting losses, and the error size depends on instrument characteristics (shape, size, windshield, heating, height above ground, wind exposition etc) and the meteorological conditions during the precipitation event (precipitation type, wind speed, air temperature, radiation, humidity), and they deliver formulas for the correction of measurements with common gauge types (Goodison et al, 1998, Figure 6). However, it is difficult to apply the corrections because the required meta data are not available for most of the gauge stations. The resulting bias of the uncorrected gauge analysis products may be trendly compensated using long-term mean correction factors, which were derived by Legates (1987), who corrected the monthly long-term-mean precipitation for about 25,000 stations using empirical correction formulas and approximated meta data. The monthly mean correction factors, which are mostly in the range of 1.0 to 3.0, describe the mean annual cycle but not the year-to-year variation. For this and for the limited accuracy of the bulk correction in principle results, that after the correction with regard to systematic measuring errors a stochastic error component is remaining. Following Legates (1995), the stochastic error of the bulk correction is estimated to 40% of the systematic correction term.

### 5.2 Sampling error

The sampling error has been investigated by GPCC using data from dense networks of Australia, Canada, Finland, Germany and USA. Based on statistical experiments performed for 322 test cases, relations were derived between the sampling error and the number of observations and spatial variability of precipitation in these regions. From Figure 7 it can be seen, that the relative sampling error of monthly precipitation is assessed between 10% and 20% with 8 gauges and between 7% and 10% with 16 stations per 2.5° gridcell (WMO 1985 and Rudolf et al. 1994).

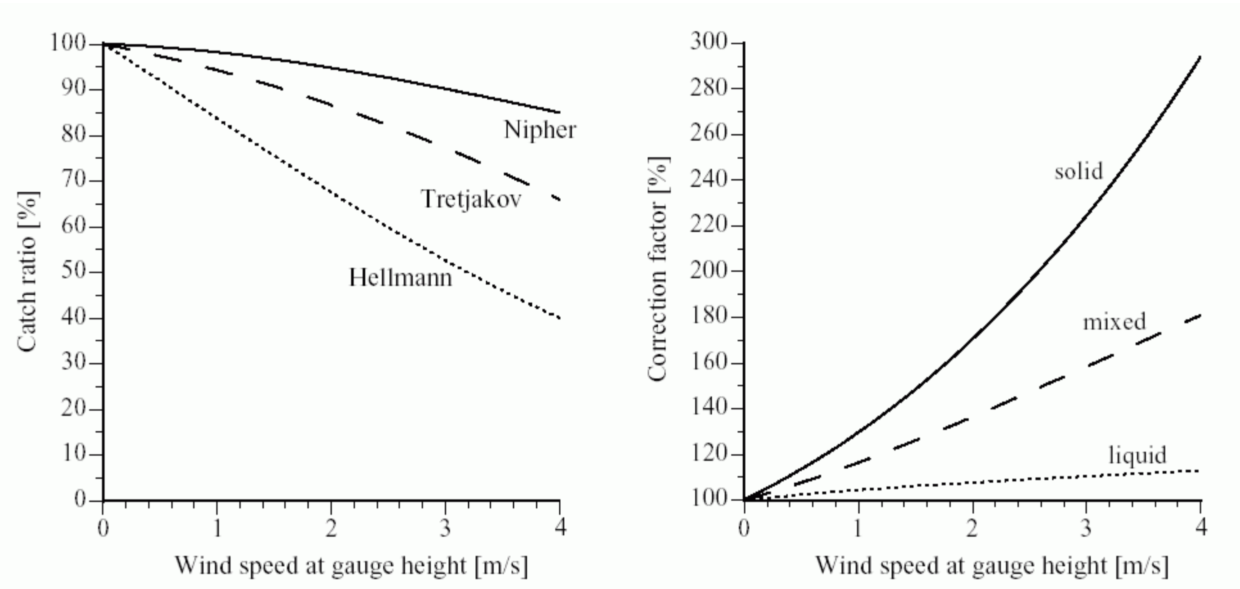


**Figure 6.** The systematic measuring error: Typical functions of catch ratio of dry snow vs. wind speed for selected gauges (left), and correction factors for the unshielded Hellmann gauge vs. wind speed for different precipitation types (right), after Goodison et al. (1998).

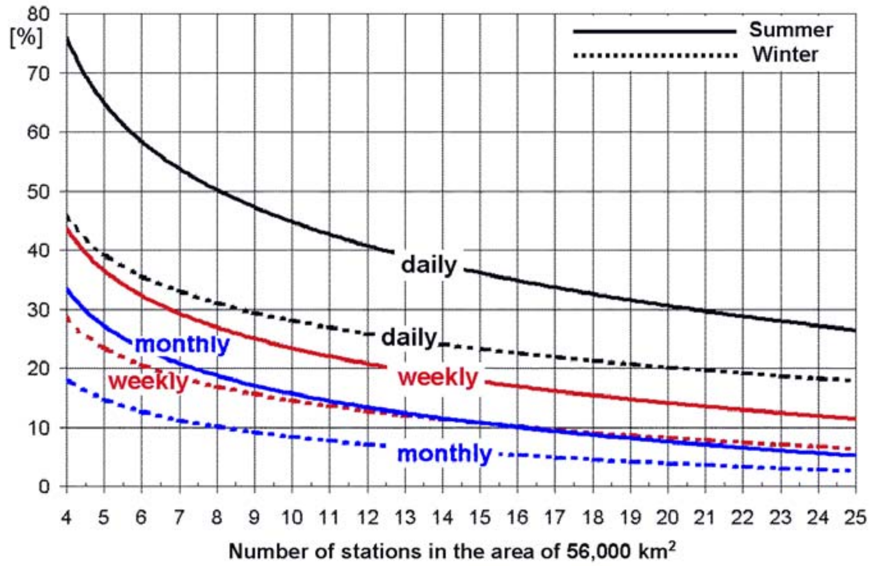


**Figure 7.** Sampling error of area-mean precipitation calculated from point observations in percent of the area-mean as a function of the number of stations for monthly, weekly and daily precipitation, under summer and winter conditions (after WMO 1985).

## 6 CHARACTERISTCS OF THE GRIDDED DATA SETS

The GPCC provides various types of gridded monthly precipitation data sets with respect to the different user requirements such as timeliness, spatial accuracy or temporal homogeneity. These are the criteria for the selection of the gauge data to be used for the respective products. The gauge-based analysis products except for the 50-year climatology (for details see Beck et al., 2005) result from the quasi-operational data management and analysis system, but they differ with regard to the number of stations included (Figure 8) and the level of data quality-control being performed. The gridded data sets are accessible via Internet with both spatial resolutions of 1.0° and 2.5° geogr. latitude by longitude.

**Characteristics of the gridded analysis products being available from the GPCC:**

- The **First Guess** of the global monthly precipitation anomaly is based on interpolated precipitation anomalies at about 4,500 stations. Monthly precipitation totals are accumulated from synoptic reports received via GTS for the considered month, and the climatic mean monthly precipitation at the same stations (1961-1990) which are selected from the GPCC global normals collection. An automatic-only quality-control (QC) has been performed for the synoptic data. The First Guess was generated starting with September 2003. Since that time, a First Guess is available within 5 days after end of the observation month.
- The **Monitoring Product** of monthly precipitation for global climate monitoring is based on SYNOP (after high level QC) and monthly CLIMAT reports from totally 7,000 stations and is available within about 2 months after observation month. The operational production started with the year 1996 and is going on to near-present. An Interim Version of the Monitoring Product covering the period 1986-1995 has been derived from similar input data in 1994/1995 after GPCC's development phase. The series has been complemented backwards to 1979 by another preliminary gauge product using the same analysis method but a reduced input data set (Xie, Rudolf, Schneider and Arkin, 1996). The Monitoring

Product supplies the in-situ component to the satellite-gauge combinations of GPCP (Huffman et al. 1995, Adler et al. 2003) and of CMAP (Xie and Arkin 1997).

- The **Full Data Product** is of much higher accuracy and recommended to be preferred for hydrometeorological studies and verification. The analysis includes all stations supplying data for the individual month. The data coverage varies from 12,000 (1951) to more than 40,000 stations (1986-1990). After 1990 the data coverage progressively decreases to the Monitoring Product data base. A new full data re-analysis is performed in irregular time intervals, which are set with respect to data base improvements. The current Version 3 of the Full Data Product covers the period from 1951 to 2004.
- The new **50-Year Climatology** supplying gridded time-series for studies on climate variability and trend is based on data being selected with respect to a (mostly) complete temporal data coverage and homogeneity of the time-series. In contrast to the other GPCC products, ordinary kriging is used for interpolation. The first version is based on time-series for 9,343 stations covering the period 1951-2000 (Beck, Grieser and Rudolf, 2005).
- The **Precipitation Normals** provide gridded long-term mean precipitation for the period 1961-1990 for the calender months, based on the mean data from about 30,000 stations. The data base comprises the normals of the WMO collection, and or normals delivered by the countries to the GPCC or calculated from data time-series at the GPCC.

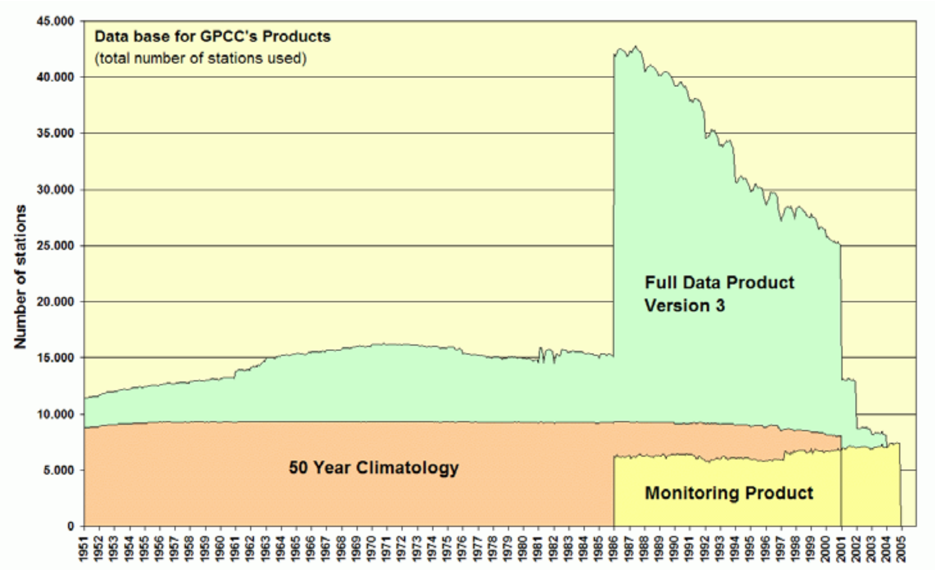


**Figure 8.** Temporal data coverage (total number of stations per month) for the GPCC products.

Following variables are calculated on the gridcells:

- Monthly precipitation totals for the individual month
- Mean monthly precipitation totals for the period 1961-1990 (“normals“)
- Monthly precipitation anomaly i.e. deviation from the mean 1961-1990
- Monthly precipitation percentage related to the mean 1961-1990
- Number of gauges used per gridcell for the individual month
- Bulk factors for assessment of systematic gauge measuring error and bias correction.

## 7. CONCLUSIONS

The Global Precipitation Climatology Centre provides various gridded precipitation data sets which are optimized with regard to different user requirements, such as timeliness, spatial resolution, accuracy or temporal homogeneity. In addition to precipitation totals, meta data on are delivered which enable the users to assess the quality of the precipitation results.

The gauge data analyses of the GPCC are used for many purposes, e.g. for adjustment of satellite data (GPCP and NCEP), for verification of model results (ECMWF Reading, MPI for Meteorology Hamburg), for drought monitoring (FAO Rome), for global hydrological studies (UNESCO World Water Development), for climate monitoring (GCOS), for education (Univ. Frankfurt a.M.). About 30 email inquiries are sent per month, mainly about specific aspects or asking for original gauge data. According to the international task of the GPCC and responsibility of the originators and owners of the gauge data, the station-related data are not distributed by the GPCC.

The GPCC counts about 7,000 Website hits and 2,000 data downloads per month. Many of the individual users are anonymous for the GPCC. We request the users to quote GPCC's Website and publications. Any direct feedback, recommendations acknowledgements by email or letter would be welcome.

**Finally some recommendations from the GPCC to the users:**

- Check which product is most suitable for the application purpose with regard to the priority of timeliness, regional accuracy or homogeneity.
- Pay attention to the accuracy-related information provided by the GPCC (number of stations, systematic error). Check the error range by consideration of the systematic error estimates and the regional number of stations used.
- Do not compare regional area-means which are calculated from data sets on different grid resolutions. The rough approximation of coastlines may cause relevant deviations between 2.5° and 1.0° based area means.
- Gridded anomalies can be generated in two different ways: (#1) calculation of the anomaly on the stations which requires the availability of both, data from the considered month and normal values, and (#2) by the relation of gridded data sets, which were separately generated for the considered month and for the normal precipitation totals. Method #1 is consistent with regard to the stations used, method #2 includes a much larger number of stations. From technical reasons, method #2 is used by the Visualizer, results based on the anomaly interpolation is available on email request.
- Reference to the GPCC is requested from the users, and feedback about the application of the products is welcome. Mail to: gpcc@dwd.de.

**For access to the gridded products and more information go to:** http://gpcc.dwd.de

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