Global Precipitation Analysis Products of the GPCC

Deutscher Wetterdienst, Abt. Hydrometeorologie,

Weltzentrum für Niederschlagsklimatologie (WZN)

Erstellt: U. Schneider,	Geprüft: M. Ziese	Freigabe: S. Hänsel
Datum: 27.05.2022	Datum: 30.05.2022	Datum: 30.05.2022
Unterschrift: Sch gez. U. Schneider	Unterschrift: Ziese gez. M. Ziese	Unterschrift: SH gez. S. Hänsel

- Änderungsdokumentation -

Revision	Geänderte Kapitel/Seiten/ Änderungsgrund	Datum	Bearbeiter	Dienststelle
000	Neuerstellung	Mai 2005	B. Rudolf	KU4
001	Aktualisierung	29.03.2007	T. Fuchs	KU42
002	Überarbeitung	21.05.2008	T. Fuchs	KU42
003	Überarbeitung	14.11.2008	U. Schneider, A. Meyer-Christoffer	KU42b
004	Überarbeitung (Änderung Org.-Bez., Erg. Im Betriebs-handbuch des WZN)	11.05.2009	U. Schneider	KU42b
005	Überarbeitung wg. neuem Release der GPCC-Produkte (Klimatologie V.2010 u. Full Data Monthly V.5)	22.12.2010	U. Schneider	KU42b
006	Überarbeitung wg. neuem Release der GPCC-Produkte (Klimatologie V.2011 u. Full Data Monthly V.6)	23.12.2011	U. Schneider	KU42b
007	Überarbeitung wg. neuem Release der GPCC-Produkte (Klimatologie V.2015 u. Full Data Monthly V.7)	13.05.2015	U. Schneider, M. Ziese	KU42b
008	Überarbeitung wg. neuem Release der GPCC-Produkte (Klimatologie V.2018 u. Full Data Monthly V.2018 (V.8))	05.06.2018	U. Schneider	KU42b
009	Überarbeitung wg. neuem Release der GPCC-Produkte (Klimatologie V.2020 u. Full Data Monthly V.2020, Monitoring Produkt V.2020, Full Data Daily V.2020)	19.01.2021	U. Schneider	KU42b
010	Überarbeitung wg. neuem Release V.2022 der GPCC-Produkte, Erweitertung der Klimatologien auf verschiedene Bezugszeiträume, verschiedene syst. Messfehler	27.05.2022	U. Schneider	KU42b

Global Precipitation Analysis Products of the GPCC

U. Schneider, P. Finger, E. Rustemeier, M. Ziese, S. Hänsel

Global Precipitation Climatology Centre (GPCC)
Deutscher Wetterdienst, Offenbach a. M., Germany, May 2022

Introduction

Precipitation plays an important role in the global energy and water cycle. Accurate knowledge of precipitation amounts reaching the land surface is of special importance for fresh water assessment and management related to land use, agriculture and hydrology, incl. risk reduction of flood and drought. High interest in long-term precipitation analyses arises from the needs to assess climate change and its impacts on all space and time scales. Based on this demand, national and international organizations initiated and support many research and monitoring programmes.

In this framework, the Global Precipitation Climatology Centre (GPCC) has been established in 1989 on request 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). Mandate of the GPCC is the global analysis of daily and monthly precipitation on the earth's landsurface based on *in situ* raingauge data. Since its start, the centre is the *in situ* component of the WCRP Global Precipitation Climatology Project (GPCP). In 1994, the long-term operation of the GPCC has been requested by WMO in order to contribute to the climate monitoring activities of the Global Climate Observing System (GCOS). Since 1999, GPCC acts also as GCOS Surface Network Monitoring Centre (GSNMC) for precipitation, the pendant one for temperature monitoring is operated by the Japan Meteorological Agency (JMA).

The aim of the GPCC is to serve user requirements especially with regard to accuracy of the gridded precipitation analyses and timeliness of the product availability. The WCRP Programme Global Energy and Water Exchanges (GEWEX) for instance requests high spatial resolution and accuracy for the last two decades, while the priority of GCOS and IPCC (Intergovernmental Panel on Climate Change) is on long-term homogeneous time-series in the framework of climate change. Timeliness of products is ensured by cut-off dates for data processing and analysis. The GPCC analysis products (except the VASClimO data set) result from the same quasi-operational data management and analysis system. However, depending on the requirements they differ with regard to the number of stations (data sources) included and the level of quality control being performed (Rudolf et al., 2011, Becker et al., 2013, Schamm et al., 2014, Schneider et al., 2014, Schneider et al., 2017).

All GPCC products, gauge-based gridded precipitation data sets for the global land surface, are available in spatial resolutions of 1.0° latitude by longitude; depending on the product additional spatial resolutions of 0.25°, 0.5° and 2.5° are available. GPCC's new global precipitation climatology V.2020 (available in 2.5°, 1.0°, 0.5° and 0.25° resolution) based on data from ca. 86,100 stations is used as background climatology for the other GPCC analyses. The database contains data from more than 124,000 different stations, being the largest precipitation database of the world. Corresponding to international agreement, station data provided by Third Parties are protected in order to respect the copyright of the data providers. However, the gridded GPCC analysis products are freely available via Internet (http://gpcc.dwd.de).

The different products of the GPCC are used world-wide by various institutions, in particular in context of water- and climate-related research and monitoring activities of WMO, WCRP, GCOS, GEWEX (poster 8th GEWEX_Open Science Conf. Canmore_201805.pdf), FAO (UN Food and Agriculture Organisation), UNESCO (UN Educational, Scientific and Cultural Organization) and GEO (Group on Earth Observations).

What's new? (recent achievements/improvements in brief)

1) Database extended from 84,800 to 86,100 stations with climatological normals
2) Enhanced/further improved QC of the station database
3) Analysis method improved (climatological infilling in data sparse areas)
4) Interpolation error (Yamamoto, 2000) added to new versions of GPCC products (precipitation climatology V.2022, Full Data Monthly V.2022 and Monitoring Product V.2022)
5) Two different estimates of mean systematic gauge-error added to GPCC precipitation climatology V.2022 (GPCC method (Fuchs et al. 2001, Schneider et al., 2017,), as well as Legates and Willmott, 1990)

For details, see the following description.

GPCC's suite of gridded precipitation analysis products

Note on GPCC's analysis methodology: GPCC's monthly precipitation analysis products described below are based on anomalies from the climatological normals at the stations (see Precipitation Climatology). The anomalies are spatially interpolated by using a modified version of the robust empirical interpolation method SPHEREMAP that is preferred by GPCC (the Climatology and Full Data Monthly Analyses are internally interpolated on a 0.25° subgrid, Monitoring Product and First Guess Analysis on a 0.5° subgrid). The method constitutes a spherical adaptation (Willmott et al., 1985) of Shepard's empirical weighting scheme (Shepard, 1968) taking into account:

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

Willmott et al. (1985) apply a weighting method for all stations beyond a minimum distance to the grid point (epsilon1, ca. 1% of the grid size). However, if stations closer are found, they only rely on those stations and apply a simple arithmetic mean for those, neglecting all stations outside this environment. This would lead to neglecting many potentially useful stations and information in areas of high station density. To avoid this the GPCC has introduced a few modifications described in Becker et al. (2013).

With regard to optimisation of the performance (in view of the potentially large number of stations involved in the interpolation process – 7,000-9,000 for the near real-time products, up to > 50,000 for the Full Data Monthly Analysis) – it is feasible to introduce an intelligent search algorithm to identify for each grid cell the closest stations to be utilized for the interpolation. Instead of ranking the distances across all stations for each grid point, we apply in advance a clustering of stations on 2º×2º grid cells and limit the search algorithm to all clusters touched by a search window being sized as 1.75 times the cluster size (here 3.5º) across the equator. Towards higher latitudes, the size of the search window is conserved in the canonical manner by scaling with the cosine of the latitude. The oversizing of the search window warrants that it does not miss stations just outside the closest clusters. Target number of stations to be ranked is 16. If the original search window finds fewer stations than the target number, the window is doubled in size and the search is repeated until the target number is reached. For latitudes higher than 87.5 degrees, the whole area is regarded as one circumpolar cluster, giving one for each polar region.

In addition to these previous SPHEREMAP modifications (Becker et al., 2013), the GPCC recognized the need to limit the interpolation of the precipitation anomalies in large data void regions, especially when extending the period of the analyses before 1901, when the overall number of stations drops significantly below 10,000 (see Figure 1), to avoid unrealistic artefacts by interpolating anomalies between different climate regimes. Therefore, GPCC applies climatological infilling for regions where an entire 5° grid is without any station for the analysis month given; in that case climatological normals are infilled for the mute stations leading to zero anomalies there for the month regarded. Figure 1 illustrates the number of stations over time with original data and with climatological normals used for climatological infilling. For periods with a good data coverage, the effect by the climatological infilling is negligible, but for periods with reduced data coverage as before 1951, and especially with poor data coverage as before 1901, it has a significant effect and helps to avoid interpolation artefacts. Figure 2 illustrates the effect of the climatological infilling for May 1891 (example from V.2018).

In addition to the analysis results with climatological infilling, the differences to the analysis without infilling are given to illustrate the effect of the infilling method. Though it is actually possible to reconstruct the analysis results without infilling, the GPCC strongly recommends to use the analysis results with climatological infilling, which helps to avoid interpolation artefacts in data sparse regions/periods.

Finally, the gridded monthly anomaly analyses are superimposed on GPCC's new background climatology (except for VASClimO data set V1.1).

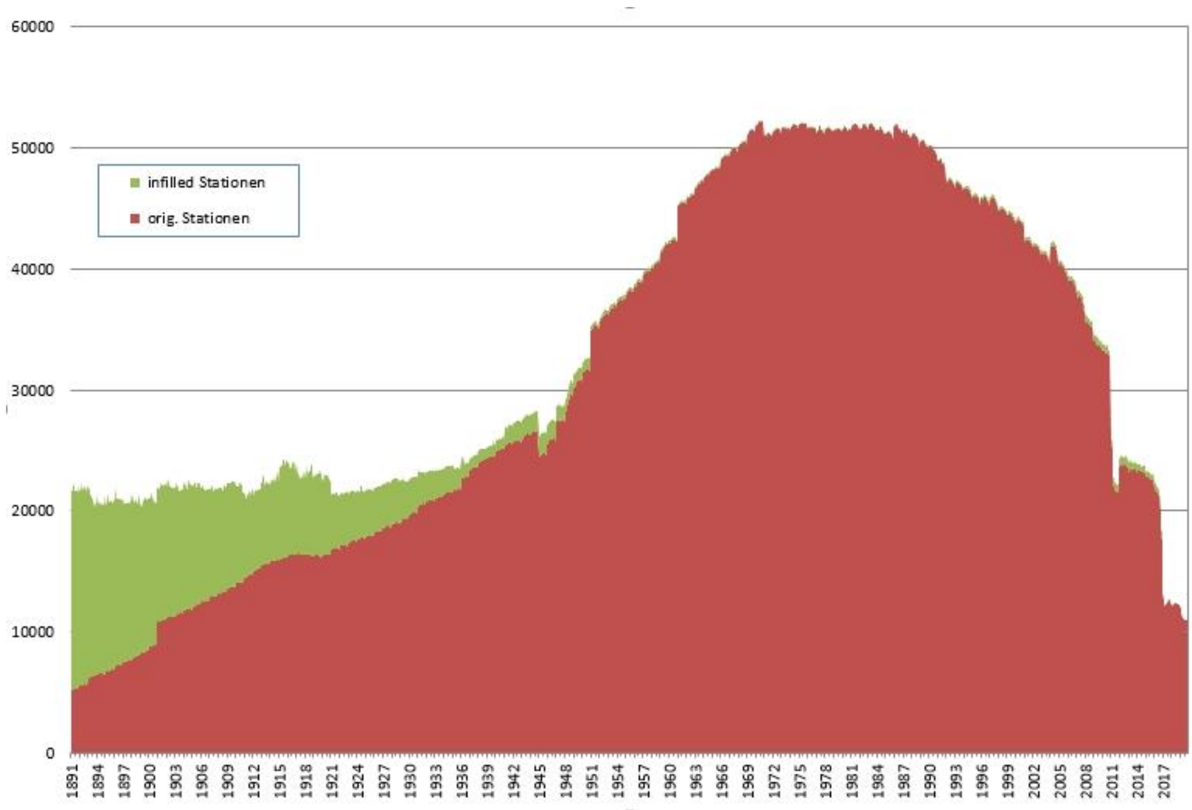

***Figure 1**: Number of monthly precipitation data over time since 1891 for GPCC's Full Data Monthly Analysis V.2020 from original stations and added by climatological infilling (similar in V. 2022)*

- The new GPCC **Precipitation Climatology** (V.2022) is focusing on the period 1951-2000 and consists of normals from ca. 86,100 stations. The climatology comprises normals collected by WMO (CLINOs), delivered by the countries to GPCC or calculated from time-series of monthly data (with at least 10 complete years of data) available in our database.

  In case that time series of sufficient length (more than 40 years) for the period 1951-2000 were not available from a specific station, then climatological normals have been calculated for 30-year reference periods within the period 1951-2000 (for 1961-1990, 1951-1980 or 1971-2000) with at least 20 years of data. If even this was not possible, normals have been calculated for other 30-year periods 1931-1960, 1941-1970, 1981-2010 or 1991-2020 or for any other period with at least 10 complete years of data. Figure 3 displays the climatological mean precipitation for July as an example. Besides for the overarching period 1951-2000 climatologies are provided also for the other 30-year reference periods mentioned above.

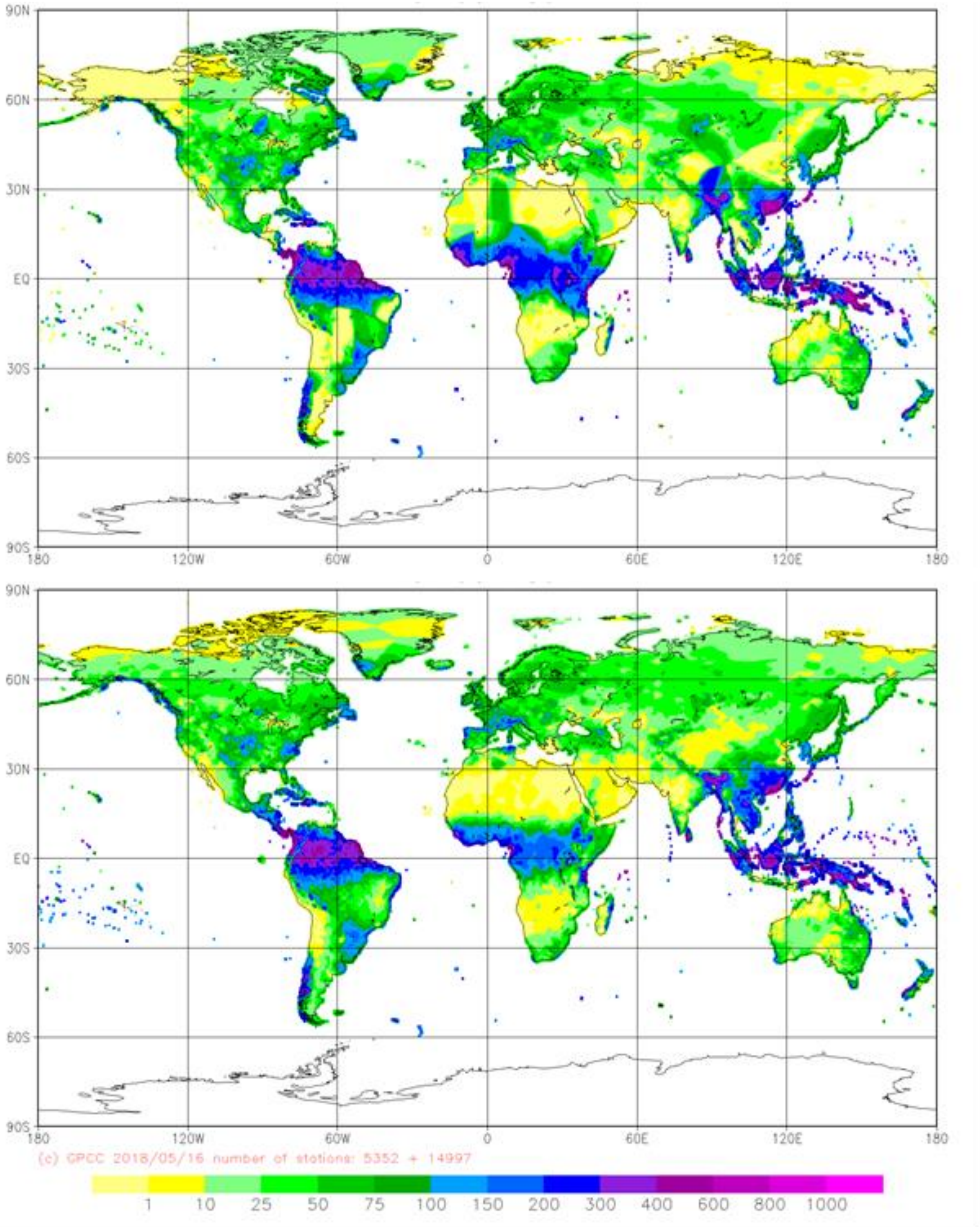

Figure 2*: GPCC's Full Data Monthly Analysis V.2018 for May 1891 (top) without and (bottom) with climatological infilling*

- The **First Guess Monthly** Product of the monthly precipitation anomaly is currently based on interpolated precipitation anomalies from more than 7,000 stations worldwide. Data sources are synoptic weather observation reports (SYNOP) received at DWD via the WMO Global Telecommunication System (GTS) and climatic mean (mainly 1951-2000, or other reference periods as described before) monthly precipitation totals at the same stations extracted from GPCC's global normals collection. An automatic-only quality control (QC) is applied to these data. Since September 2003, GPCC First Guess Monthly precipitation analyses are available within 5 days after the end of an observation month. Main application purpose is to serve as input for near-realtime drought monitoring applications, e.g. by the GPCC, the FAO and the University of London Hazard Research Centre.
- The **First Guess Daily** Product of daily precipitation totals is currently based on data from more than 7,000 stations with an automatic-only QC. Here, the relative anomaly (daily total to monthly total) is applied instead of the absolute anomaly of the monthly products. The daily relative anomalies at the stations are interpolated by means of an ordinary block Kriging scheme with one global variogram. Daily gridded relative anomalies are multiplied by the gridded monthly total (from the First Guess Monthly Product) to get the daily totals (Schamm et al., 2014). It is released together with the First Guess Monthly Product within 5 days after the observation month.

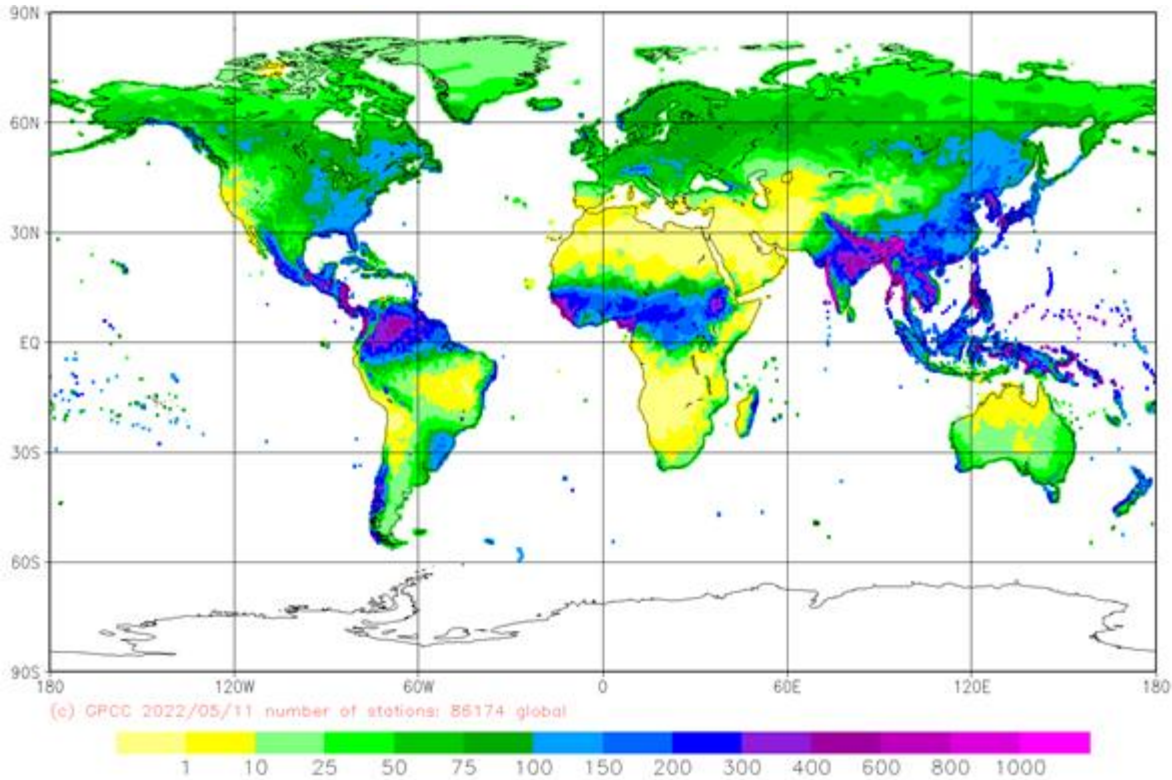

***Figure 3**: Climatological mean precipitation for July (based on GPCC's new Precipitation Climatology V.2022 focusing on the period 1951-2000, 0.25° resolution)*

- The **Monitoring Product** of monthly precipitation for global climate monitoring is based on SYNOP reports received at DWD and CPC/NOAA and monthly CLIMAT reports received near-real time via GTS from ca. 7,000 –9,000 stations (after high level QC) and is available within 2 months after observation month. This is the GPCC product with the longest history: Operational monthly analysis started with the year 1986 and has continuously been updated every month since then as well as extended back to 1982. The analyses are based on automatic and intensive manual quality control of the input data. The GPCC Monitoring Product is the *in situ* component of the satellite-gauge combined precipitation analyses of GPCP (Huffman et al. 1995, Adler et al. 2003, Adler et al., 2018) and of CMAP (Xie and Arkin 1997). It also supports regional climate monitoring. **Figure 4** illustrates the heavy rainfall in Pakistan during the La Niña event in summer 2010.

- The **Full Data Monthly** Product V.2022 is of much higher accuracy compared to the GPCC near real-time products mentioned above. Therefore, its application is recommended for hydrometeorological model verification and water cycle studies, e.g. in context of UNESCO, GEWEX, and GTN-H (Global Terrestrial Network for Hydrology). This analysis product is based on all stations, near real-time and non real-time, in the GPCC database supplying data for the individual month for which a climatological normal is available (for details see Precipitation Climatology). The GPCC Full Data Monthly Product Version V.2022 has been extended to cover the entire period from 1891 to 2020, using the new GPCC Precipitation Climatology V.2022 as analysis background. The data coverage per month varies from only 6,000 stations in 1891 to more than 55,000 (Figure 7) in the best-covered months of 1986. The Full Data Monthly Product is being updated at irregular time intervals subsequent to significant database improvements.
- The **Full Data Daily** Product V.2022 is based on near- as well as non-real time data. It was extended in time to cover the period from 1982 to 2020 and is based on up to 40,000 stations per month. In comparison to the First Guess Daily Product, the data basis and quality control is significantly enhanced. Since the release of the V.2018, the interpolation scheme was changed from ordinary block Kriging to the modified SPHEREMAP scheme as utilized to produce GPCC's monthly precipitation analyses. As before, anomalies of the daily precipitation relative to the monthly total at that station were interpolated. Therefore, also this analysis uses only the stations that also feature a monthly precipitation total.
- The VASClimO 50-Year Data Set supplying gridded time-series of monthly precipitation for the global land areas for the period 1951-2000 for climate variability and trend studies was based on data of 9,343 stations with a coverage of at least 90% over the period. It was developed at the GPCC in the research project VASClimO (Beck, Grieser and Rudolf, 2005); it is being replaced by the new homogenized precipitation analysis HOMPRA covering the extended period 1951-2005, which will be based on a significantly larger number of stations. The data set **HOMPRA-Europe** V.1 based on more than 5,500 stations was released in 2017; V.2 for the extended period 1951-2010 based on more than 8,100 stations covering at least 80% of the time period will become available in spring 2021. The other continents will follow depending on the success of the homogenization progress; a homogenized analysis for South Africa is currently in preparation.
- The **GPCC drought index** **(GPCC-DI)** is a combination of the Standardized Precipitation Index (SPI, McKee et al., 1993) and the Standardized Precipitation Evapotranspiration Index (SPEI, Vicente-Serrano et al., 2009). It is based on GPCCs First Guess Product and NOAAs NCEP CPC GHCN_CAMS data set (Fan & van den Dool, 2008) with the parameterization from Thornthwaite (1948) for the potential evapotranspiration (PET). Aggregation periods of 1, 3, 6, 9, 12, 24 and 48 months are calculated. The data are available within 10 to 13 days after the end of the observation month (Ziese et al, 2014).
- The **Interpolation Test Dataset** (ITD) was created based on freely available GHCN stations for 1 year (1988) to provide users the opportunity to compare their interpolation schemes with the GPCC results. This dataset contains monthly gridded precipitation totals along with the input station metadata. The ITD is not intended to be applied for any climatological studies but to provide users the opportunity to verify the interpolation methods applied by GPCC, e.g. by own reinterpolation from the original data.

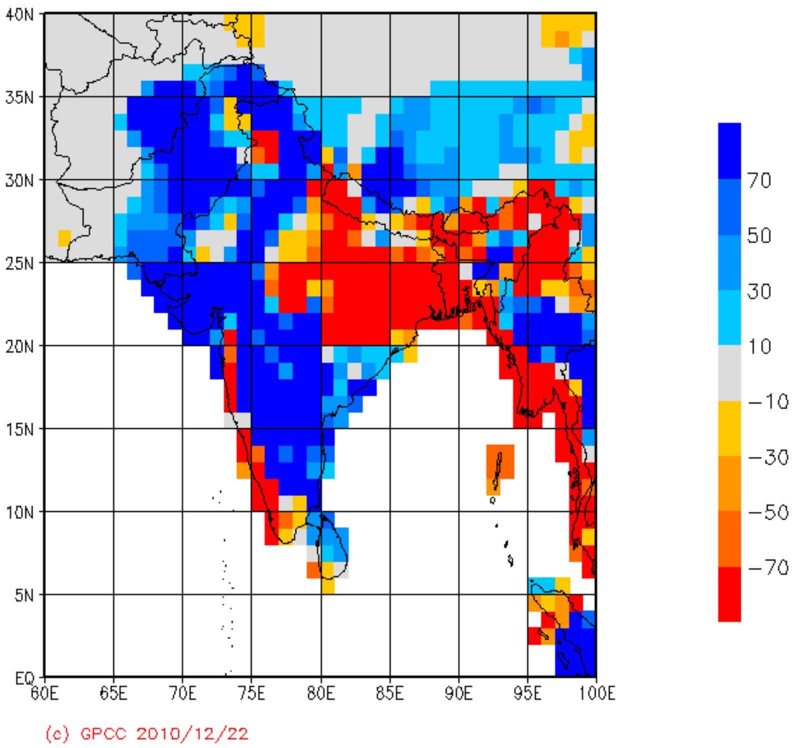

Figure 4: *Example of monthly precipitation anomalies in August 2010 (La Niña event) for Pakistan/India (based on GPCC Monitoring Product, 1.0° resolution)*

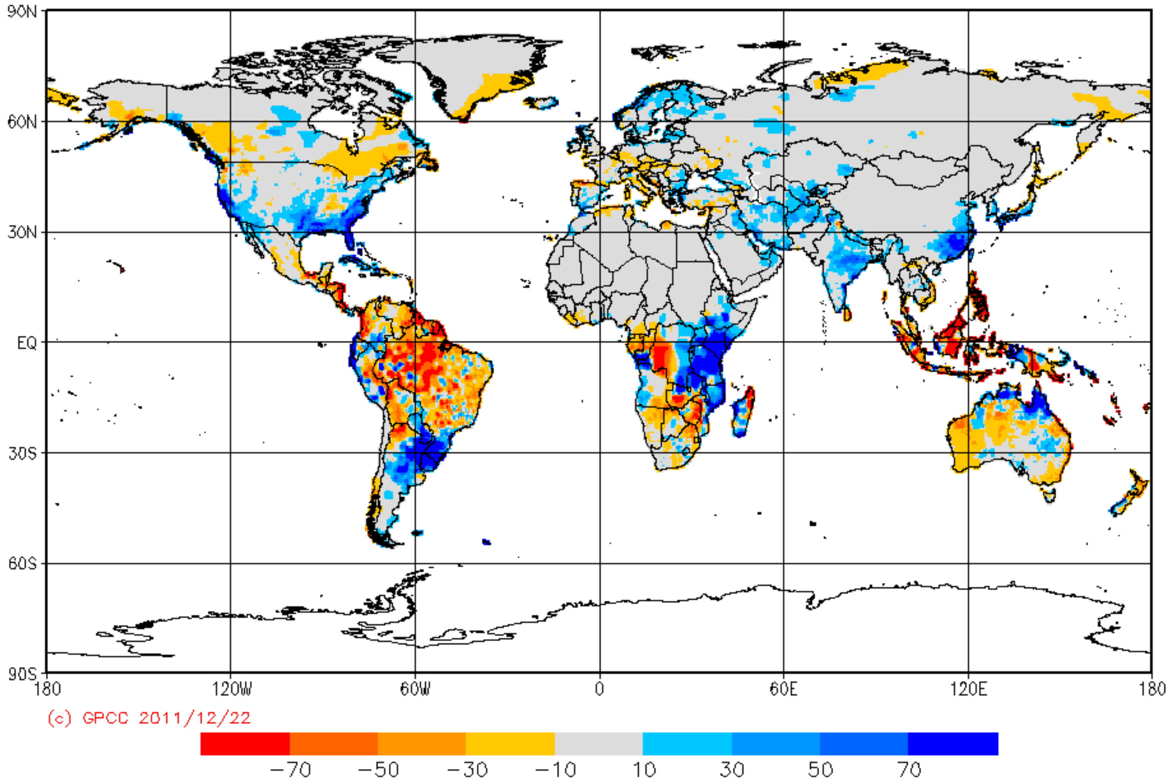

Figure 5: *Example of precipitation anomalies in DJF 1997/1998 (El Niño event) in mm/month (based on GPCC Full Data Product V.5, 0.5° resolution)*

GPCC analyses are well suited to study relations of large-scale precipitation regimes to changes in atmospheric circulation patterns like El Nino/Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) as can be seen from **Figure 6** showing the correlation patterns between between monthly time series of gridded precipitation anomalies for the period 1901-March 2011 and ENSO and NAO indices.

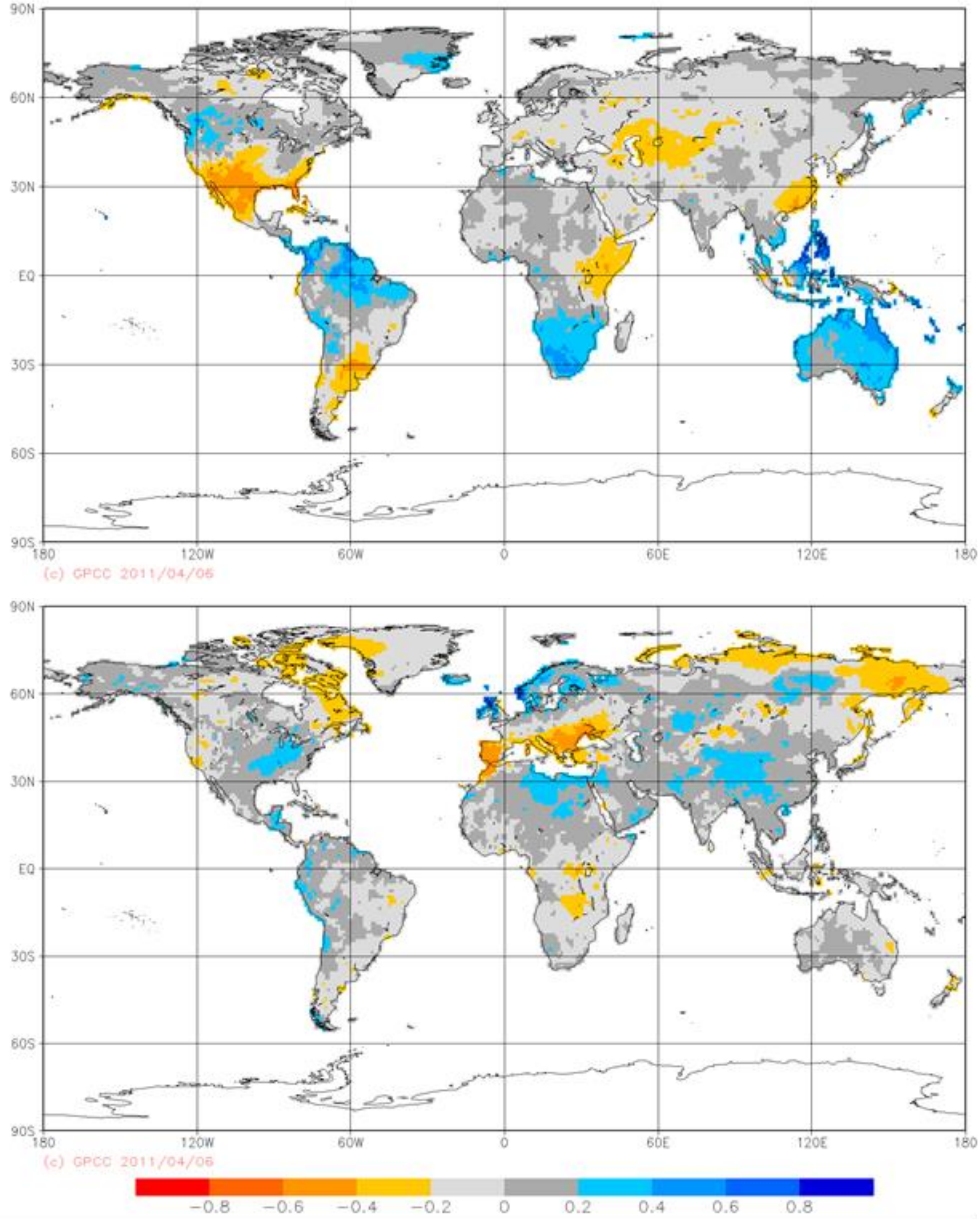

***Figure 6**: Correlation between monthly time series of gridded precipitation anomalies for the period 1901-March 2011 and (top) SOI and (bottom) NAO index (based on GPCC Full Data Monthly V.5, 0.5° resolution, since Jan. 2010 Monitoring Product V.3)*

The GPCC Database

The accuracy of raingauge based precipitation analyses mainly depends on the spatial density of stations being used. In order to calculate monthly area-mean precipitation on 2.5° gridboxes with a sampling error of not more than 10%, between 8 and 16 stations per gridbox are needed (WMO 1985, Rudolf et al. 1994), and even more for daily analyses. For the global land-surface this accuracy requirement, as requested by the GPCP implementation and data management plan (WMO, 1990), adds up to 40,000 equally distributed stations worldwide.

We distinguish two types of observed precipitation data with regard to their timeliness: data being available near real-time (based on synoptic weather observation data and climate reports exchanged via the WMO GTS), and additional data being obtained with a larger time delay. The GPCC provides a set of different products in order to address competing archetype requirements like timeliness and accuracy. For example, a near real-time analysis is requested by some international programmes for various applications, but the database available near real-time is insufficient in many regions with regard to the requested product accuracy (in addition to the spatial density of stations the quality-control (QC) of station metadata and precipitation data performed is crucial (see section GPCC data processing).

GPCC near real-time database

The database for GPCC's Monitoring Product is merged from three sources: monthly precipitation totals derived from synoptic weather reports (SYNOP) at the DWD, Germany, and at CPC/NOAA, USA, and monthly precipitation totals extracted from CLIMAT-bulletins received at the DWD and JMA. The database available near real-time comprises ca. 7,000–9,000 stations and provides in some regions a sufficient database for quantitative precipitation estimates, if the grid resolution is not too high. Users are advised to carefully take into account the number of stations per grid, which is provided as additional information to every GPCC product. Within the data pool, the CLIMAT data – after a quality check – are of higher quality and provide a reference for quality assessment of the SYNOP-based data.

The GPCC First Guess Products (monthly and daily) include the DWD SYNOP-based monthly precipitation totals from more than 7,000 stations.

GPCC Full database

With respect to the limited real-time availability of raingauge data, additional data from dense national observation networks of individual countries are collected at the GPCC. Recommendation letters of the WMO support the data acquisition. So far, National Meteorological and/or Hydrological Services (NMHSs) from about 190 countries of the world contributed data to the GPCC. However, the delay of the deliveries varies between 1-5 years or even more due to the processing time needed by the data originators (Figure 7 and Figure 8).

In addition, other available global and regional collections of climate data (Global Historical Climatology Network, GHCN; University of East Anglia Climate Research Unit, CRU; FAO; GEWEX related projects; Asia-Pacific/Matsumoto, former Soviet Union/Groisman; Africa/ Nicholson) have been integrated in the GPCC database. Thereby GPCC has compiled the most comprehensive global collection of monthly and daily precipitation data from *in situ* observations (Figures 7-10). To respect the interests by the data originators (NMHSs), the GPCC cannot redistribute the station related precipitation data and metadata to other parties.

The temporal data coverage of the monthly GPCC products is illustrated in Figure 7. The near real-time First-Guess Monthly analyses are including precipitation totals accumulated from SYNOP reports received at DWD. For GPCC's Monitoring Product all SYNOP and CLIMAT data are used if available within ca. 1 month after observation.

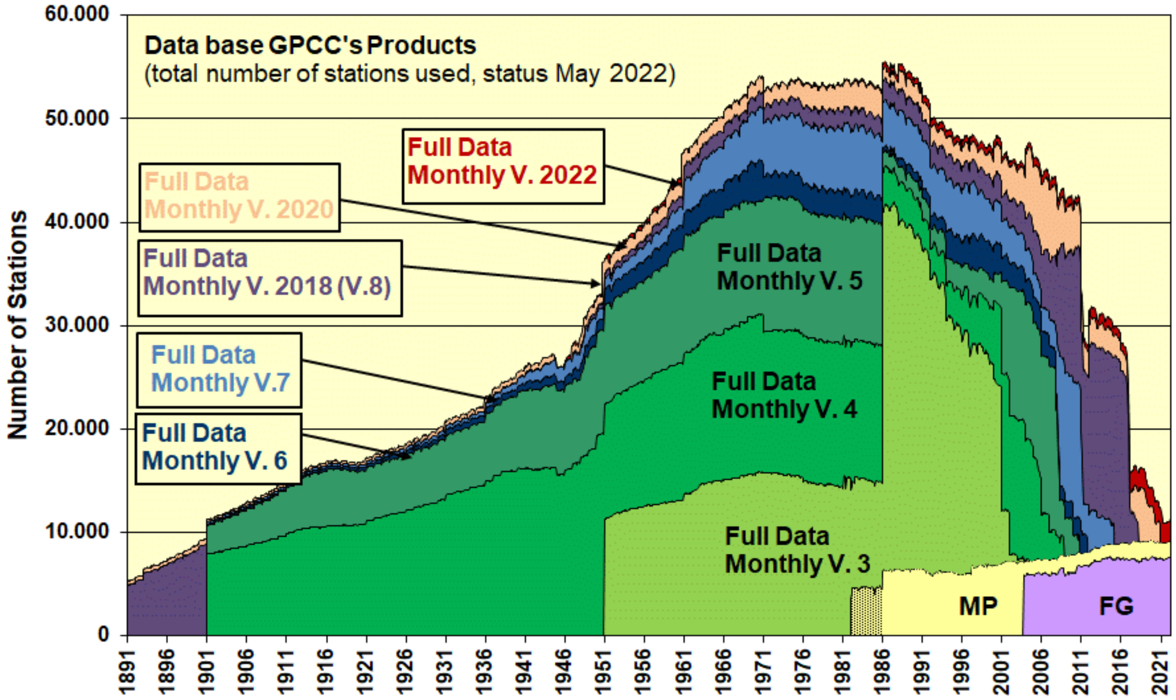

Figure 7: Total number of stations used for the GPCC products (Near real-time First-Guess Monthly Product “FG”, Monitoring Product “MP”; non real-time Full Data Monthly Product (Versions 3 to 8, V.2020 and V.2022))

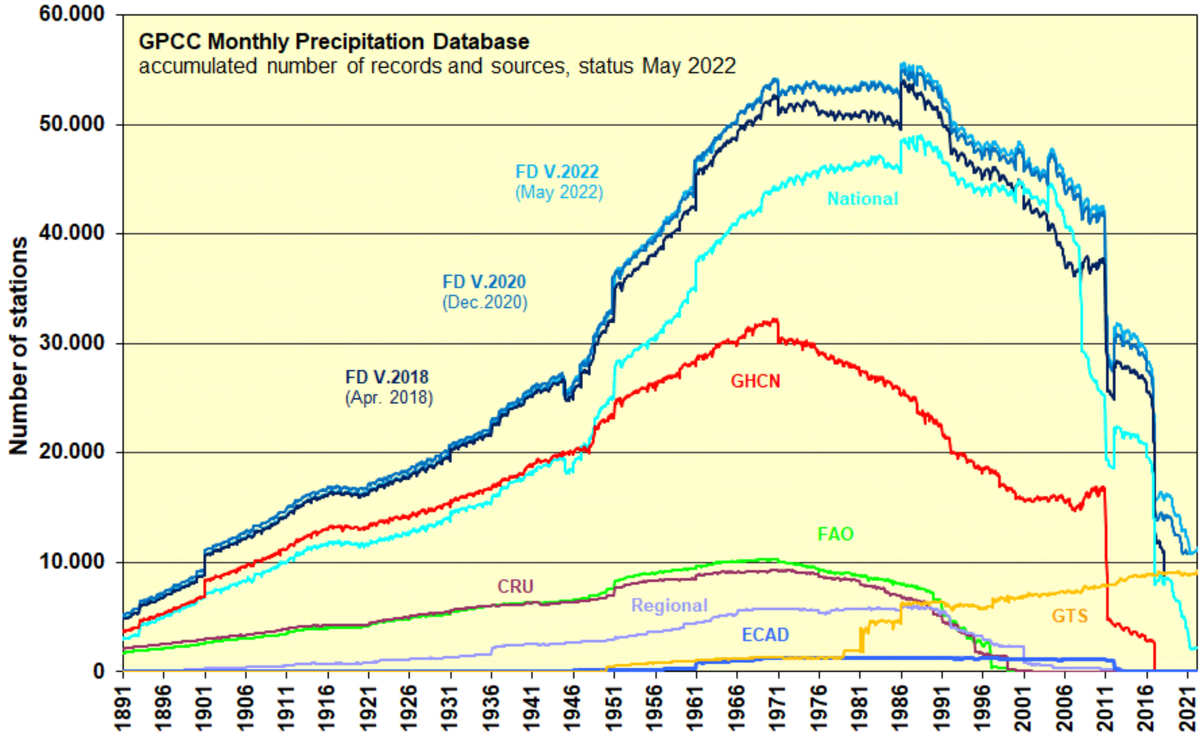

***Figure 8**: Total number of stations with monthly precipitation data in GPCC’s full database according to the different data sources*

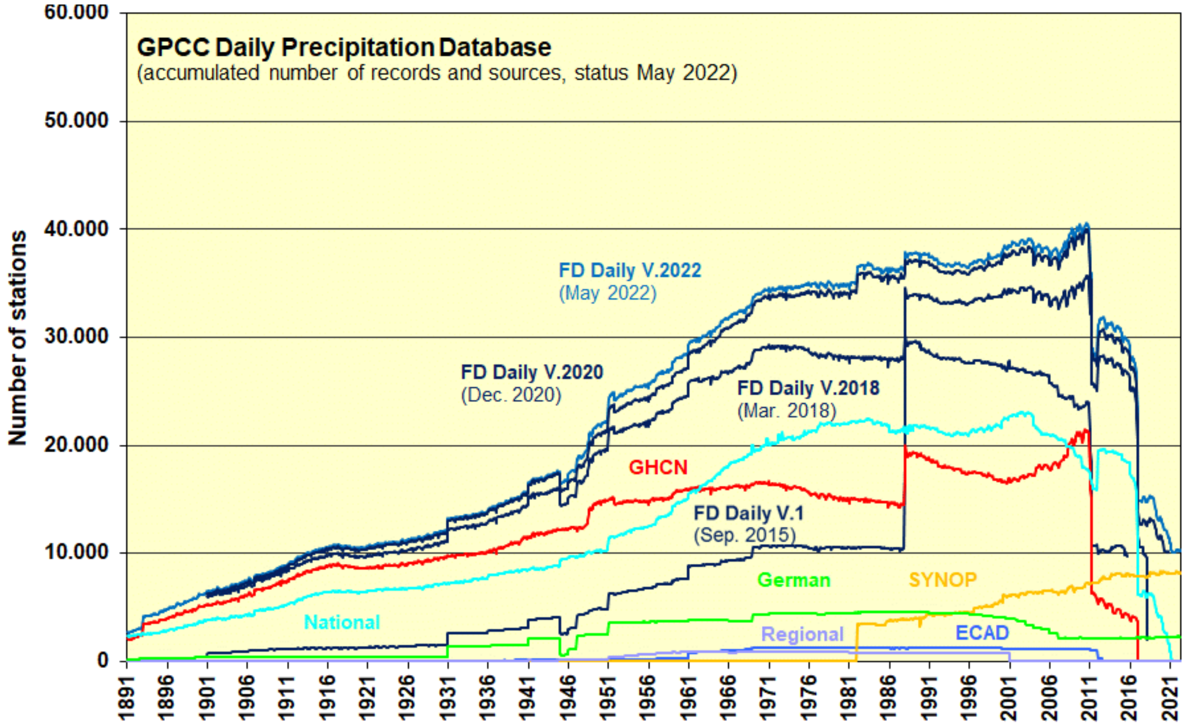

__Figure 9__: Total number of stations with daily precipitation data in GPCC's full database according to the different data sources for different versions of GPCC Full Data Daily (V.1 of 09/2015, V.2 03/2018, V.12/2020 and V.2022)

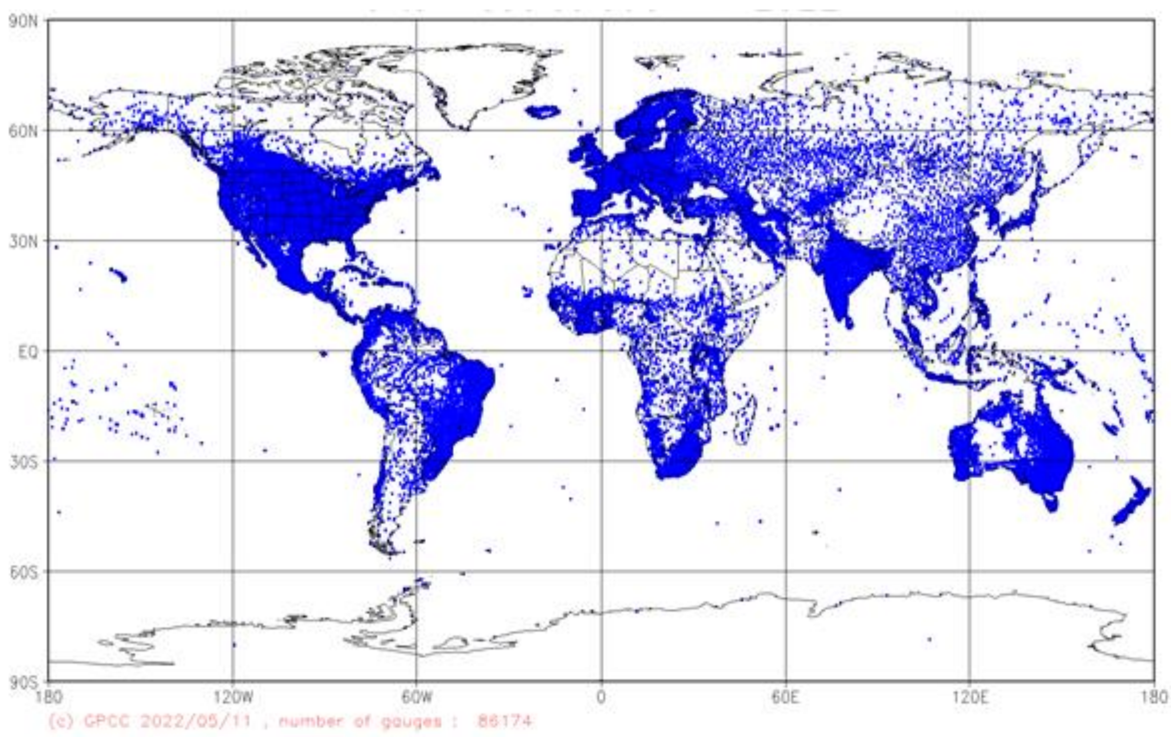

__Figure 10__: Spatial distribution of monthly in-situ stations with a climatological precipitation normal, based on at least 10 years of data in GPCC's database (number of stations in July: 86,174)

The Full Data Products (monthly and daily) include all data being supplied later by the individual countries, if the stations have a climatological normal (at least 10 years of data, fragments of time-series are not used any more). The years with the best data coverage are 1970 and 1986-1987 with data for more than 54,000 stations. The decrease of the number of stations from more than 45,000 in 1961-2000 down to 10,000 stations after 2019 is caused by the delay of the data delivery to and by post-processing at GPCC. The database continuously increases by delivery of updates for recent years, supplements with additional stations and complementation by long time-series of data. All data suppliers are encouraged to provide annual updates to GPCC. GPCC updates its non real-time products at irregular time intervals subsequent to significant database improvements. Figure 8 shows the contribution of the individual data sources to GPCC's full monthly database, as Figure 9 for the daily data base,.Figure 10 gives the spatial distribution of the stations with climatological normals for July.

The GPCC Data Processing

All data reaching the GPCC are checked, processed, reformatted and integrated in a Relational Database Management System (RDBMS). Since 2009, all data being imported into the RDBMS are checked against background statistics enabling the GPCC to detect and correct data errors in this early stage. Within the data bank, the records from the different sources (SYNOP, CLIMAT, national data etc.) are stored in parallel (source specific slots) under addition of quality flags indicating the results of data processing. By this an intercomparison and crosscheck is possible, which is very helpful in the quality-control (QC) and product generation process.

The data processing steps include QC and harmonization of the metadata (station identification), quality-assessment of the precipitation data, selection and intercomparison of the data from the different sources for the particular products is described in Schneider et al. (2014), the interpolation of the station-related data to a regular mesh system, and calculation of the spatial means on the 2.5°, 1.0° and 0.5° latitude/longitude gridbox area is described in Becker et al. (2013). The Full Data Monthly, as well as the Precipitation Climatology are available on a 0.25° resolution, too. For additional information, please consult GPCC's website (http://gpcc.dwd.de).

In GPCC's non-realtime products (Full Data Monthly V.2020) as well as in the processing of near-realtime products (Monitoring Product, First Guess Monthly Analysis) the normals as in GPCC's precipitation climatology (focussing on the period 1951-2000) are used.

About the accuracy of the gridded results

The two major error sources are: (1) The systematic measuring error that results from evaporation out of the gauge and aerodynamic effects, when droplets or snowflakes are drifted by the wind across the gauge funnel, and (2) The stochastic sampling error due to a sparse network density. The GPCC provides a gridded quantification for the following errors:

The systematic gauge-measuring error is – except for very specific situations – an undercatch of the true precipitation. Parameters affecting the efficiency of measurement are features of the instrument used (size, shape, exposition etc.) and the meteorological conditions (wind, precipitation type, air temperature, humidity, radiation) during the precipitation event. This information is not available for most of the precipitation stations. The global distribution of the error has been estimated for long-term mean precipitation (Legates and Willmott, 1990) and is provided as climatological mean for each calendar month. The error is large in snow regions respectively in cold seasons. On the basis of SYNOP reports the GPCC developed a new on-event correction method for systematic gauge measuring errors (Fuchs et al., 2001). This event-based correction is usually smaller than the climatological correction, however it is still a rough bias estimate based only on wind, weather, temperature and humidity data from synoptic observations of ca. 7,000 stations available worldwide. The GPCC data files now contain both versions of the systematic gauge measuring error.

The sampling error of gridded monthly precipitation data has been quantified by GPCC for various regions of the world. Based on statistical experiments using data from very dense networks, the relative sampling error of gridded monthly precipitation is between ± 7 to 40% of the true area-mean, if 5 raingauges are used, and with 10 stations the error can be expected within the range of ± 5% and 20% (Rudolf et al. 1994). The error range for a given number of stations represents the spatial variability of precipitation in the considered region.

Access to GPCC's gridded products

The different gridded data sets of GPCC are freely available from our Website http://gpcc.dwd.de.

Monthly precipitation data sets can be visualized in maps like Figure 3 or **Figure 4** or downloaded using the GPCC-Visualizer (**Figure 11**).

GPCC provides all gridded data sets (daily and monthly temporal resolution) as netCDF-files via its download gate (https://opendata.dwd.de/climate_environment/GPCC/html/download_gate.html) and recommends the users to fetch the files from this source.

More information about the variables provided is given in the data set landing pages and in the metadata of the netCDF-files.

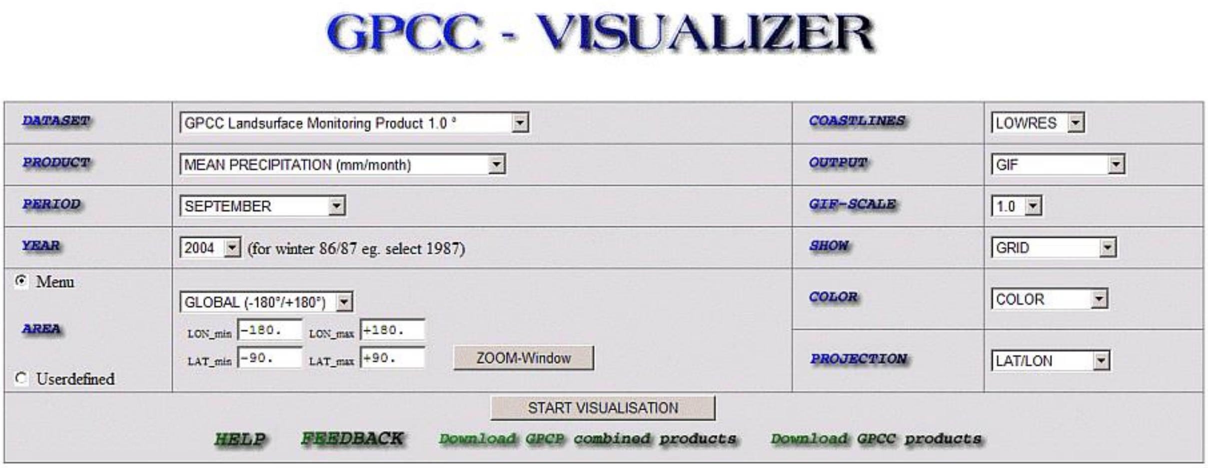

Figure 11*: GPCC Visualizer for online visualization and download of gridded GPCC products*

Some hints and recommendations to GPCC product 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 per grid, 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 that 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.
- When analysing long–term climate variability and changes do not combine different GPCC products available for different periods, which may cause discontinuities in time. Only the GPCC VASClimO and HOMPRA products are adjusted to support long-term precipitation variability and trend analyses.

- 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. For technical reasons, the Visualizer uses method #2, results based on the anomaly interpolation are available on email request.
- Reference to the GPCC is requested from the users, and feedback about the application of the products is very welcome. You might provide your feedback to gpcc@dwd.de.

The GPCC kindly requests all responsible national agencies to follow the WMO call for data and to provide the GPCC with the required precipitation and metadata. The analysis results are of high importance e.g. concerning the verification of global climate models and climate variability studies based on observed data. The analysis results of the GPCC are published and freely accessible. However, the station-related data delivered by the countries will not be distributed to third parties, in order to respect and protect the ownership of the originators.

Acknowledgements:

Deutscher Wetterdienst (DWD, National Meteorological Service of Germany) operates the GPCC under the auspices of the World Meteorological Organization (WMO). The German Federal Ministry of Education and Research (BMBF) within the German Climate Research Programme supported the research project VASClimO, contributing to the development of the 50 year data set.

A special thank is addressed to all data contributors, which mostly are National Meteorological and/or Hydrological Services of the world but also some other institutes. Their data contributions enable the GPCC to do its global precipitation analyses described in this document.

References:

Adler, R.F., G.J. Huffman, A. Chang, R. Ferraro, P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, P. Arkin and E. Nelkin (2003): The Version-2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation analysis (1979-present). J. Hydrometeorol., 4, 1147–1167.

Adler, R.F., M.R.P. Sapiano, G.J. Huffman, J.-J. Wang, G. Gu, D. Bolvin, L. Chiu, U. Schneider, A. Becker, E. Nelkin, P. Xie, R. Ferraro and D.-B. Shin (2018): The Global Precipitation Climatology Project (GPCP) aonthly analysis (new version 2.3) and a review of 2017 global precipitation. Atmosphere, ***9***, 138; DOI: 10.3390/atmos9040138.

Beck, C., J. Grieser and B. Rudolf (2005): A New Monthly Precipitation Climatology for the Global Land Areas for the Period 1951 to 2000. DWD, Klimastatusbericht 2004, 181-190.

Becker, A., P. Finger, A. Meyer-Christoffer, B. Rudolf, K. Schamm, U. Schneider and M. Ziese (2013): A description of the global land-surface precipitation data products of the Global Precipitation Climatology Centre with sample applications including centennial (trend) analysis from 1901–present. Earth Syst. Sci. Data Disc. 5: 921-998, DOI: 10.5194/essd-5-71-2013.

Fan, Y. and H. van den Dool (2004): Climate Prediction Center global monthly soil moisture data set at 0.5° resolution for 1948 to present, J. Geophys. Res., 109, D10102.

Fuchs, T., J. Rapp, F. Rubel and B. Rudolf (2001): Correction of Synoptic Precipitation Observations due to Systematic Measuring Errors with Special Regard to Precipitation Phases. Phys.Chem. Earth (B), Vol. 26, No. 9, 689-693.

Huffman, G. J., R. F. Adler, B. Rudolf, U. Schneider, and P. R. Keehn (1995): Global precipitation estimates based on a technique for combining satellite-based estimates, rain gauge analysis, and NWP model precipitation information. J. Climate, 8, 1285-1295.

Legates, D. R., and C. J. Willmott (1990): Mean seasonal and spatial variability in gauge-corrected, global precipitation. Int. J. Climatol., 10, 111-127.

Rudolf, B., and U. Schneider (2005): Calculation of gridded precipitation data for the global land-surface using in-situ gauge observations. Proceedings of the second Workshop of the International Precipitation Working Group IPWG, Monterey, October 2004, 231-247.

Rudolf, B., A. Becker, U. Schneider, A. Meyer-Christoffer and M. Ziese (2011): New Full Data Reanalysis Version 5 provides high-quality gridded monthly precipitation data. GEWEX News, Vol. 21, No. 2, 4-5, May 2011.

Schamm, K., M. Ziese, A. Becker, P. Finger, A. Meyer-Christoffer and U. Schneider (2014): Global gridded precipitation over land: a description of the new GPCC First Guess Daily product. Earth Syst. Sci. Data 6(1):49-60, DOI: 10.5194/essd-6-49-2014.

Schneider, U., A. Becker, P. Finger, A. Meyer-Christoffer, M. Ziese and B. Rudolf (2014): GPCC's new land surface precipitation climatology based on quality-controlled in situ data and its role in quantifying the global water cycle. Theor. Appl. Climatology 115, 15-40, DOI: 10.1007/s00704-013-0860-x.

Schneider, U., P. Finger, A. Meyer-Christoffer, E. Rustemeier, M. Ziese and A. Becker (2017): Evaluating the hydrological cycle over land using the newly-corrected precipitation climatology from the Global Precipitation Climatology Centre (GPCC)", Atmosphere, 8 (3), 52, DOI: 10.3390/atmos8030052.

Shepard, D. (1968): A two-dimensional interpolation function for irregularly spaced data. Proc. 23rd ACM Nat. Conf., Brandon/Systems Press, Princeton, NJ, 517-524.

Thornthwaite, C. (1948): An approach towards a rational classification of climate, Geographical Review, 38, 55-94

Willmott, C.J., C.M. Rowe and W.D. Philpot (1985): Small-scale climate maps: A sensitivity analysis of some common assumptions associated with grid-point interpolation and contouring. Amer. Cartogr., 12, 5-16.

WMO (1985): Review of requirements for area-averaged precipitation data, surface based and space based estimation techniques, space and time sampling, accuracy and error, data exchange. WCP-100, WMO/TD-No. 115.

WMO (1990): The Global Precipitation Climatology Project - Implementation and Data Management Plan. WMO/TD-No. 367, 47 pp. and 6 Appendices, Geneva, 1990.

Xie, P. and P.A. Arkin (1997): Global Precipitation: a 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. Bull. Amer. Meteorol. Soc. 78, 2539 - 2558.

Yamamoto, J.K. (2000): An alternative measure of the reliability of ordinary Kriging estimates, Mathematical Geology 32, Springer, May 2000, 489-509.

Ziese, M., U. Schneider, A. Meyer-Christoffer, K. Schamm, J. Vido, P. Finger, P. Bissolli, S.

Pietzsch and A. Becker (2014): The GPCC Drought Index - a new, combined and gridded global drought index, Earth System Science Data, 2014, 6, 285-295. DOI: 10.5194/essd-6-285-2014

Global Precipitation Climatology Centre
c/o Deutscher Wetterdienst
P.O. Box 10 04 65
63004 Offenbach a. M.
Germany

Tel.: +49 - 69 - 8062 2900
Fax: +49 - 69 - 8062 3987
E-Mail: gpcc@dwd.de
Web: http://gpcc.dwd.de