National Aeronautics and Space Administration Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for Global Precipitation Climatology Project Version 3.1 Daily Precipitation Data

Last Revised June 9, 2021

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Revision History

Revision Date	***Changes***	***Author***
June 9, 2021	Original	George Huffman

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1.0 Introduction

Precipitation observations are critical to research and many applications, including drought monitoring, flash floods, crop forecasting, disease prediction, and ocean salinity studies. Rain gauges are the primary source of direct precipitation observations. Unfortunately, rain gauges are point measurements and much of the globe is sparsely covered, especially in underdeveloped countries and areas of low population density. Furthermore, with the exception of a few buoy arrays, there are no precipitation gauge observations over the open ocean. Satellites seek to mitigate the limitations of rain gauge observations by estimating precipitation over land and ocean for most, or all, of the entire globe. When converted to gridded precipitation estimates, the satellite observations facilitate a multitude of studies, including those on the larger space-time scales that gauge analyses typically cannot provide. To augment the satellite-based precipitation estimates, uniformly processed gauge analyses are incorporated to improve the land-based estimates.

The Global Precipitation Climatology Project (GPCP) is a community-based activity of the Global Water and Energy Exchange (GEWEX) project in the World Climate Research Programme (WCRP), focused on creating a global, long-term homogeneous record of gridded precipitation estimates and ancillary information for use in climate studies and other applications. GPCP Version 3 is being developed as the successor to the highly successful GPCPV2 data set. This document introduces the GPCPV3.1 Daily product; the Monthly has been released, and the 3-hourly product is being developed.

This latest release, labeled V3.1 is considered stable but has known limitations. Specifically, the TOVS/AIRS record is not as homogeneous as we expect for a CDR. The team continues to work toward improving these issues in a future release.

1.1 Dataset/Mission Instrument Description

The GPCPV3.1 Daily data set provides a gridded (Level 3) homogeneously processed record of global precipitation estimates at 0.5° spatial and daily temporal resolution. The current data span is (June 2000-December 2019) with the potential to extend this record in the future. The current daily product provides the following data fields:

(1) merged satellite-gauge precipitation estimate, and
(2) probability of liquid-phase precipitation.

1.1.1 GPCPV3.1 Daily

The GPCPV3.1 Daily estimates rely on a relatively homogeneous record of satellite precipitation estimates as input. Most of the spatial coverage is provided by the Integrated Multi-satellitE Retrievals for GPM (IMERG), which is the unified U.S. multi-satellite precipitation product for the U.S. GPM team. The precipitation estimates from the various precipitation-relevant satellite passive microwave (PMW) sensors comprising the GPM constellation are computed using the 2017 version of the Goddard Profiling Algorithm (GPROF2017), then gridded, intercalibrated to the GPM Combined Radar Radiometer Analysis product (with GPCP V2.3 climatological calibration), and combined into half-hourly 0.1°x0.1° fields. These are provided to the Climate Prediction Center (CPC) Morphing-Kalman Filter (CMORPH-KF) quasi-Lagrangian time interpolation procedure and the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks – Cloud Classification System (PERSIANN-CCS) infrared (IR) re-calibration procedure. In parallel, the Modern Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) vertically integrated vapor (TQV) fields are used in the CMORPH-KF quasi-Lagrangian time interpolation procedure. The PERSIANN-CCS estimates are computed (supported by an asynchronous re-calibration cycle) and sent to the CMORPH-KF quasi-Lagrangian time interpolation procedure. The CMORPH-KF quasi-Lagrangian time interpolation (supported by an asynchronous KF weights updating cycle) uses the PMW and IR estimates to create half-hourly estimates. The IMERG Final Run is used, which is computed ~3.5 months after the observation month and incorporates the the Deutscher Wetterdienst (DWD) Global Precipitation Climatology Centre monthly gauge analysis (GPCC; Schneider et al. 2017; Schneider et al. 2014; Becker et al. 2013). The Final Run half-hour estimates are calibrated so that they sum to the monthly satellite-gauge Final Run combination, and then summed to the 0.5° daily scale for GPCP V3.1 Daily. The current standard reference is Huffman et al. (2020), augmented by the IMERG ATBD (Huffman et al. 2019), posted at *https://gpm.nasa.gov/sites/default/files/2020-05/IMERG_ATBD_V06.3.pdf* . For high-latitude areas, the NASA/GSFC Sounder Research Team provides precipitation estimates from the Television-InfraRed Operational Satellite (TIROS) Operational Vertical Sounder (TOVS) sensors that flew on selected TIROS- and NOAA-series satellites, and on the Advanced Infrared Sounder (AIRS) instrument aboard the Earth Observing System Aqua satellite (Susskind and Pfaendtner 1989; Susskind et al. 1997; Susskind et al. 2003; Susskind et al. 2014). These data are merged via a set of algorithms to take advantage of the strengths of each data set and minimize the weaknesses to create a single, best precipitation estimate with associated ancillary fields. A brief algorithm description is provided in the next section.

1.2 Algorithm Background

The basis of the GPCPV3.1 Daily algorithm is to use state-of-the-art estimates of daily precipitation over the globe and calibrate them to the GPCP V3.1 Monthly to control bias and create a consistent downscaling of the Monthly.

The TOVS record is calibrated to the AIRS record off-line, so the two sources are considered to provide an approximately uniform record. TOVS/AIRS is adjusted to IMERG using regionally (3x3 template of the 1°x1° gridboxes) and seasonally varying histograms of daily precipitation rates. In the polar regions where IMERG lacks data (either seasonally or persistently), the matched histograms are smooth-filled[1] to provide calibration for TOVS/AIRS. As well, the IMERG-calibrated TOVS/AIRS is bias-adjusted to the GPCP V3.1 Monthly (Huffman et al. 2021b) to ensure a reasonable bias for joining to the IMERG data region.

Preliminary work showed that the fine temporal sampling in IMERG tended to depict too much light precipitation, resulting in a mis-match with the TOVS/AIRS data, so the daily IMERG is thresholded at 0.24 mm/d. For simplicity in this initial release, IMERG is used in the latitude band 55°N-S, and TOVS/AIRS is used at higher latitudes. The boundaries at 55° N and S show some discontinuities in some daily precipitation fields, so a light, empirically developed "feathering" is applied. Then for each gridbox, all the days are ratio-adjusted to approximately sum to the GPCP V3.1 Monthly. Since the Monthly is strongly influenced by the precipitation gauge analysis, the adjustment ratios for the Daily are capped in the range 0.2-4.0 to prevent mismatches between precipitation gauge and satellite values from driving unrealistically high rates for the few days of occurrence in regions where precipitation events are sparse.

As well, the field of Probability of Liquid Precipitation Phase (PLPP) is computed based on MERRA-2 analyses of surface temperature, humidity, and pressure using a diagnostic lookup table developed by Sims and Liu (2015). Following Sims and Liu, the not-liquid precipitation class is "solid" (snow, graupel, etc.), while the relatively rare "mixed" precipitation class (both liquid and solid in a single observation) is included in "liquid", since mixed is presumed to generally melt and therefore be a liquid. At the daily scale, the PLPP is computed as the fraction of the daily accumulation that fell as liquid. In the IMERG zone, the daily PLPP is computed as the precipitation-rate-weighted average of all half-hourly probabilities in the day, except for grid boxes where zero precipitation is estimated for the day, in which case it is the simple average of all available probabilities in the day. This approach assumes that the occurrence of liquid and solid over the day will approximately conform to the percentages given in the specification equation, so that the weighted PLPP approximates the fraction of amount of precipitation: liquid precipitation = probability * precipitation, and solid precipitation = (100 – probability) * precipitation. In the regions where (daily) TOVS/AIRS estimates are used, the daily PLPP is the

[1] Smooth-filling is an iterative process. On each pass, the value in every gridbox that originally was "missing" is replaced by the average of (non-missing) values on the stated template (here, 3 gridboxes in the X and Y directions). This continues until the data field (approximately) converges.

simple average of the 48 half-hourly PLPP in the day since IMERG is not available in parts of that region.

Details of the algorithm can be found in Huffman et al. (2021a).

1.3 Data Limitations

GPCPV3.1 Daily is the first release of the GPCPV3 Daily data set and is considered stable but has some known limitations. Specifically, both the IMERG and TOVS/AIRS records are not as homogeneous as we expect for a CDR. Users should account for these limitations in the use of the V3.1 Daily data. The team continues to work toward improving these issues in a future release.

The GPCPV3.1 Daily data set was carefully constructed to produce global, relatively homogeneous precipitation estimates, so users should use all estimates provided. The quality is considered highest over tropical oceans, and decreases as one moves to land areas and cooler regions, with the polar regions being the least confident.

1.3.1 Data Citation

The data set source should be acknowledged when the data are used. The American Meteorological Society guidelines contain suggested formats for referencing data sets (*https://www.ametsoc.org/ams/index.cfm/publications/authors/journal-and-bams-authors/formatting-and-manuscript-components/references/dataset-references/*). Following their example for data that are dynamically updated with uniformly computed processing runs:

Huffman, G.J., A. Behrangi, D.T. Bolvin, E.J. Nelkin, 2021: GPCP Version 3.1 Daily Precipitation Data Set, last updated June 9, 2021. GES DISC, Greenbelt, MD, accessed June 9, 2021, https://doi.org/10.5067/MEASURES/GPCP/DATA303 .

1.3.2 Contact Information

If you have general questions or comments regarding the GPCPV3.1 Daily data set, please contact George Huffman (*george.j.huffman@nasa.gov*), while questions about accessing and reading the data should be directed to Zhong Liu (*zhong.liu-1@nasa.gov*).

1.4 What's New?

This is the first release of the GPCPV3.1 Daily,

2.0 Data Organization

The dataset consists of daily data, one file per day.

2.1 File Naming Convention

GPCPDAY_L3_yyyymmdd**_V3.1.nc4**

Where:
- yyyy = 4 digit year number [2000 - 2019]
- mm = 2 digit month number [01-12, except only 06-12 for 2000]
- dd = 2-digit day number [01-31]

Filename example: GPCPDAY_L3_20070201_V3.1.nc4

2.2 File Format and Structure

Data set files are in netCDF version 4 format developed at the University Corporation for Atmospheric Research (UCAR) and Unidata (https://www.unidata.ucar.edu/software/netcdf/), with extensions that facilitate the creation of Grid, Point, and Swath data structures. The GPCPV3.1 Daily dataset uses the Grid structure.

2.3 Key Science Data Fields

See tables in Section 3.3 for lists of data fields.

3.0 Data Contents

3.1 Dimensions

Each netCDF file contains three dimensions:

latitude – latitude of the center of each row of data (WGS84 reference datum). This one-dimensional array has 360 elements.

longitude – longitude of the center of each column of data (WGS84 reference datum). This one-dimensional array has 720 elements.

time – the begin and end times of the day in minutes since January 1, 1979 00:00. This two-dimensional array has 1 x 2 elements.

3.2 Global Attributes

In addition to SDS arrays containing variables and dimension scales, global metadata is also stored in the files. Some metadata are required by standard conventions, some are provided to meet data provenance requirements, and others are provided as a convenience to users of GPCPV3.1 products. A summary of global attributes present in all files is shown in Table 1.

Table 1. Global metadata attributes associated with each SDS.

Attribute Name	Description	Data Type
ShortName	GES DISC short name	string
LongName	GES DISC long name	string
VersionID	version identification number	string
GranuleID	dataset file name	string
Format	dataset format (netCDF-4)	string
RangeBeginningDate	data begin date	string
RangeBeginningTime	data begin time	string
RangeEndingDate	data end date	string
RangeEndingTime	data end time	string
ProductionDateTime	file production date time	string
Conventions	file convention (CF-1.5)	string
NorthernmostLatitude	northernmost latitude contained in the file	float
SouthernmostLatitude	southernmost latitude contained in the file	float
WesternmostLongitude	westernmost longitude contained in the file	float
EasternmostLongitude	easternmost longitude contained in the file	float
LatitudeResolution	latitudinal resolution of the data	float
LongitudeResolution	longitudinal resolution of the data	float
Entry_ID	GES DISC dataset identifier	string
Entry_Title	GES DISC dataset title	string
title	description of the dataset	string
Science_Keywords	dataset keywords	string
ISO_Topic_Category	ISO standard dataset category	string
Data_Center_ShortName	GES DISC short name	string
Data_Center_LongName	GES DISC long name	string
Data_Center_URL	GES DISC URL	string
Data_Center_Role	GES DISC role	string
Data_Center_Last_Name	GES DISC support group name	string

Table 1, continued.

Attribute Name	Description	Data Type
Data_Center_Email	GES DISC email	string
Data_Center_Phone	GES DISC phone number	string
Data_Center_Fax	GES DISC Fax number	string
Data_Center_Address	GES DISC address	string
Data_Set_Progress	current state of the dataset	string
Data_Set_Quality	description of the quality of the dataset	string
Summary	description of the dataset	string
Validation_Data	data used to validate the dataset	string
source	dataset input sources	string
history	dataset history	string
MapProjection	dataset map projection	string
Dataset_Creator	dataset creators	string
Dataset_Title	full dataset title	string
Dataset_Series_Name	dataset name	string
Dataset_Release_Date	release date of current dataset	string
Datset_Release_Place	address of current release	string
Dataset_Publisher	publisher of current dataset	string
IdentifierProductDOI	dataset DOI	string
Data_Presentation_Form	dataset type	string
references	dataset references	string
Role	role identifier (science investigator)	string
First_Name	first name of investigator	string
Last_Name	last name of investigator	string
Phone	phone number of science investigator	string
FAX	fax number of science investigator	string
Email	email of science investigator	string
Contact_Address	street address of science investigator	string
City	city of science investigator	string
Province_or_State	state of science investigator	string
Postal_Code	zip code of science investigator	string
Country	country of science investigator	string
Use_Constraints	constraints on the use of the dataset	string
Distribution_Media	form of dataset access	string
Distribution_Size	size of dataset file	string
Distribution_Format	dataset format (netCDF-4)	string
IdentifierProductDOIAuthority	DOI authority	string
Fees	costs for use of the dataset	string
ProcessingLevel	dataset processing level	string
institution	where the data were produced	string
comment	comment on the dataset	string

A list of key metadata fields is given in Table 2. These and other metadata fields can found in the ”**CoreMetadata.0**” global attribute. Global attributes in a GPCPV3.1 file can be viewed with *ncdump* software as described in Section 4.1 [*ncdump –h –c <GPCPV3.1 file>*].

Table 2. Key Metadata Items

Name	Type	Description
_FillValue	float or short int	Value used to identify missing data.
long_name	string	ad hoc description of the variable.
valid_range	float or short int	valid data value ranges for the variable
units	string	The units of the variable.
cell_methods	string	Temporal unit of data

3.3 Products/Parameters

The list of data fields contained in each GPCP V3.1 Daily dataset is given in Table 3, together with brief descriptions and native units.

Table 3. Data fields in the GPCP V3.1 Daily dataset. The latitude/longitude use the WGS84 reference datum.

Data Field Name	Description	Units
lat	latitude of the center of the grid element	degrees_north
lon	longitude of the center of the grid element	degrees_east
time	begin date and time of the data	minutes since 1979-01-01 00:00:00
precip	precipitation estimate	mm/day
probability_liquid_precip	probability of liquid phase precipitation	percent

4.0 Options for Reading the Data

It is important that the GPCPV3.1 Daily be as accessible as possible to a wide range of users. The MEaSUREs project selected netCDF as it is designed to store scientific data and is easily accessible with command-line tools and standard application packages. If you have trouble reading the data please contact Zhong Liu at zhong.liu-1@nasa.gov.

4.1 Command Line Utilities

There are several built-in netCDF utilities that are available to access the GPCPV3.1 Daily data. See *https://www.unidata.ucar.edu/software/netcdf* for a complete list of netCDF command-line utilities. The most useful is *ncdump*:

ncdump

The ncdump tool can be used as a simple browser for netCDF data files, to display the dimension names and sizes; variable names, types, and shapes; attribute names and values. The most common use of ncdump is with the –h option, in which only the header information is displayed.

```
ncdump [-c|-h] [-v ...] [[-b|-f] [c|f]] [-l len] [-n name] [-d n[,n]] filename
Options/Arguments:
    [-c]  Coordinate variable data and header information
    [-h]  Header information only, no data
    [-v var1[,...]]  Data for variable(s) <var1>,... only data
    [-f [c|f]]  Full annotations for C or Fortran indices in data
    [-l len]  Line length maximum in data section (default 80)
    [-n name]  Name for netCDF (default derived from file name)
    [-d n[,n]]  Approximate floating-point values with less precision
    filename  File name of input netCDF file
```

4.2 Tools/Programming

Any application package that supports the netCDF file format can be used to read these data. If you are new to netCDF or to the GPCP V3.1 datasets, the following tool might be a useful starting point:

- Panoply **(***https://www.giss.nasa.gov/tools/panoply/*)

For more advanced users or programmers:

- C/C++
- Fortran 90/95
- GrADS (*http://cola.gmu.edu/grads/*)
- IDL (*http://www.harrisgeospatial.com/SoftwareTechnology/IDL.aspx*)
- Java
- Matlab (*http://www.mathworks.com/products/matlab/*)
- Python

As well, the GPCP V3.1 Daily data are accessible through the Giovanni web-based visualization and analysis application, *https://giovanni.gsfc.nasa.gov/giovanni/.*

5.0 Data Services

The data are currently available through the **Data Holdings** page of the **MEaSUREs portal** at *https://disc.gsfc.nasa.gov/measures*.

If you need assistance or wish to report a problem:
Email: gsfc-dl-help-disc@mail.nasa.gov
Voice: 301-614-5224
Fax: 301-614-5268
Address:
Goddard Earth Sciences Data and Information Services Center NASA Goddard Space Flight Center Code 610.2 Greenbelt, MD 20771 USA

6.0 More Information

For more information on our project or data, please refer to the Algorithm Theoretical Basis Document (Huffman et al. 2021).

7.0 Acknowledgements

This project is funded by NASA's Making Earth Science Data Records for Use in Research Environments (MEaSUREs) Program, which is managed by Dr. Lucia Tsaoussi.

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